IN TWO SECTIONS—SECTION ONE

MECHANICAL ENGINEERING

THE JOURNAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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IN THIS NUMBER

AN IMPROVED WEIR FOR GAGING IN OPEN CHANNELS
By Clemens Herschel, Past-President American Society of Civil Engineers

THE GERMAN LONG-RANGE GUN
By Lieut.-Col. H. W. Miller, Ordnance Department Artillery Division, U. S. A.

FEBRUARY 1920

PUBLISHED MONTHLY BY THE SOCIETY
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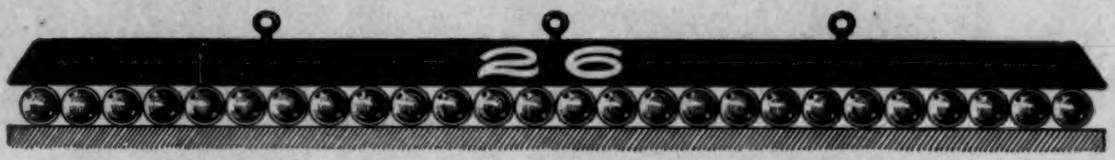
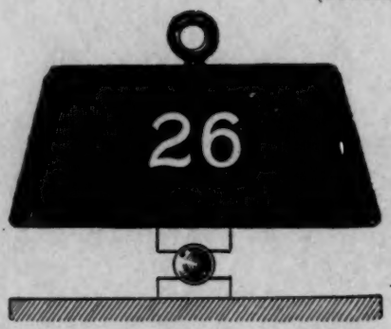


26 BALLS will carry more load than 1

(Rolling Between Plane Surfaces)



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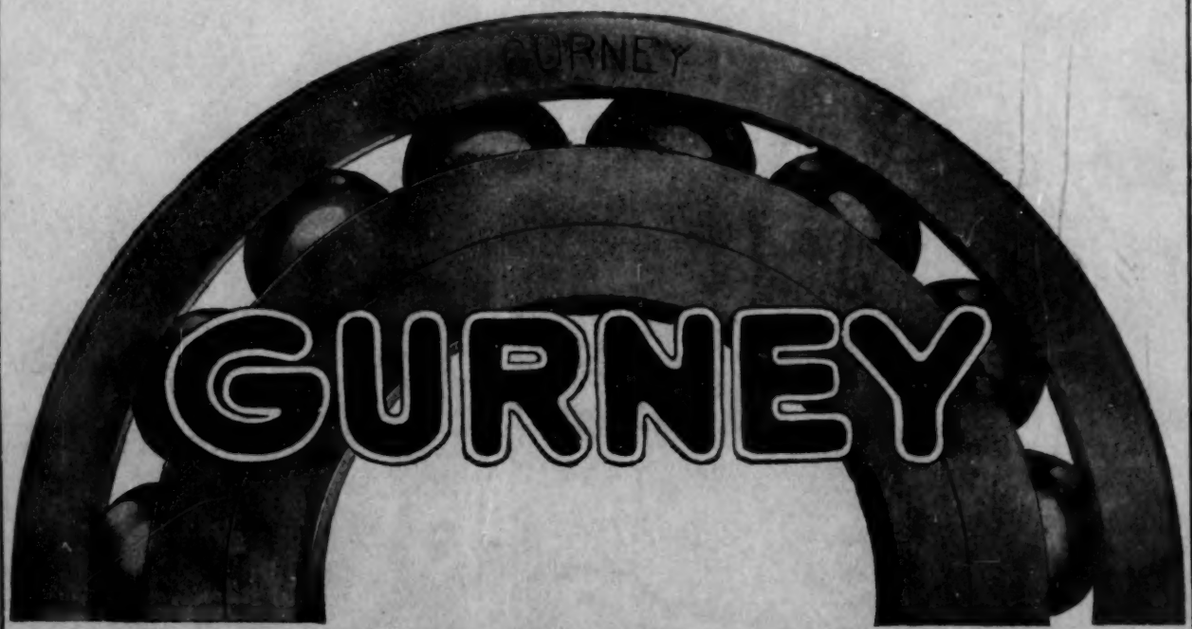

Mechanical Engineering

The Journal of The American Society of Mechanical Engineers

VOLUME 42 FEBRUARY, 1920 NUMBER 2

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Spring Meeting of The American Society of Mechanical Engineers

To Be Held at St. Louis, Mo., May 24-27

The plans for the Spring Meeting of The American Society of Mechanical Engineers are well advanced and, as announced on page 128 of this number, several sessions have already been arranged. The Local Committee of St. Louis have their plans under way for the reception of their guests, and it can be assured that the unqualified success of the Spring Meetings of recent years will again be realized and that the meeting will prove both profitable and interesting to all who attend.

The Committee on Meetings and Program has designated March 15 as the latest date on which papers can be received for presentation at the Spring Meeting. Those who are expecting to contribute papers are requested to notify the Secretary of the Society, Mr. Calvin W. Rice, immediately, giving the subject of the paper and a synopsis of its contents. All papers are first submitted to the Committee for approval, and those assigned to the meeting are printed in pamphlet form for advance distribution and published in abstract in Mechanical Engineering.

Contributors and Contributions in This Number of Mechanical Engineering

Clemens Herschel, Past President, American Society of Civil Engineers

The first article in this number is an important paper on an Improved Type of Weir for the Measurement of the Flow of Water, devised by Mr. Clemens Herschel, the distinguished hydraulic engineer, who is perhaps best known through his development of the Venturi meter for the measurement of the flow of fluids.

Lieutenant-Colonel H. W. Miller, Artillery Division, Ordnance Department, U.S.A.

An article by Colonel Miller on the German Long-Range Gun presents for the first time authentic information upon the design and operation of the gun which bombarded Paris from a distance of over 70 miles, and led to all manner of conjecture as to its type and details of construction. Colonel Miller was designated by the War Department to investigate heavy artillery of all countries, used during the war.

Papers on Research

Dean Charles R. Richards, College of Engineering, University of Illinois, has contributed a paper to the Research Department on the engineering laboratories of the University and the work in progress there. Probably a greater variety of research work is now being done at the University of Illinois than at any other similar institution in the country.

From Purdue University, another paper is contributed by Dean C. H. Benjamin, on the apparatus installed there for testing farm tractors.

C. F. Hirshfeld, chief of the research department of the Detroit Edison Company, has a brief paper on Research and Social Evolution which aroused a great deal of interest at the Mid-West Meeting of The American Society of Mechanical Engineers, held at Indianapolis last October.

Papers on Public Affairs

In accordance with its usual custom, MECHANICAL ENGINEERING presents this month a summary of important matters relating to the engineers' activities in Society and public affairs. There will be found an account of the meeting held at Washington in January by delegates from over 100 societies and engineering organizations, to discuss the establishment of a national Department of Public Works to replace the present Department of the Interior of the United States Government.

Another meeting which is reported is that of the American Economic Association at which a valuable paper was presented by Dr. Royal Meeker, summarizing the main facts with regard to employees' representation in management.

Still another trend of the times is indicated in the report just issued of a committee of the Engineering Council to consider the whole matter of the classification and compensation of engineers.

A survey of post-war conditions as affecting mechanical engineers in particular has recently been made by the president of the British Institution of Mechanical Engineers, a synopsis of which is given in Part 2 of this number.

As usual, there is a summary of Government activities with which engineers are concerned, as reported by the Washington office of the Engineering Council; a notation upon the work of the Committee on Flanges of the A.S.M.E. by a contributor to a recent meeting of the American Water Works Association; an account of the Washington Award of the Western Society of Engineers to Herbert Hoover; and an account of the presentation to Charles F. Rand of an appropriate testimonial upon his retirement as President from the United Engineering Society.

MECHANICAL ENGINEERING

THE JOURNAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Volume 42 February, 1920 Number 2

An Improved Weir for Gaging in Open Channels

By CLEMENS HERSCHEL,[1] NEW YORK, N. Y.

In the following paper are presented the results of a series of investigations on weirs which should mark an epoch in the measurement of water by that means. Asked by the Power Test Code Committee of The American Society of Mechanical Engineers to advise it with regard to weir measurements, and supplied by Engineering Foundation with the necessary funds to conduct the experiments, the author devised an entirely new weir which was tested in the Hydraulic Laboratory of the Massachusetts Institute of Technology. The tests revealed that for discharges of from 0 to 9.55 cu. ft. per sec. per ft. of weir length, the limits covered by the experiments, the quantity of water flowing, Q, was directly proportional to the difference, d, in two pressures, one measured just upstream of the weir—corrected automatically for the velocity of approach, and the other measured at the crest, the formula being: $Q = 5.50\ d$. *The weir, which bears no resemblance to the sharp-edged weir now in use, has a 2:1 slope of approach to the crest. The crest is made in the form of an arc of a circle and is hollow for observing the pressure at that point. The nappe of the stream is supported for a short distance beyond the crest by another 2:1 slope. The paper opens with a résumé of the history of weir measurements and contains descriptions and diagrams of the apparatus and tests of the new weir, with tabular and graphic reports of the results obtained.*

> "Daniel Bernoulli often said to me to eschew all those complicated formulæ; he believing that nature works according to laws that are too simple to lead to them; and if one finds such, that it is because one's computations have been based on false preliminary assumptions."—R. Wolf, Biographies Relating to the History of Civilization in Switzerland[2], Vol. 3, (1860), p. 176.

TO ANY ONE whose memory of hydraulic engineering in the United States, more especially in New England, runs back 60, or only 50, years, the standing at that time of the "Francis formula" for weir discharge will appear as little short of infallibility, or of perfection. Courts of justice recognized it as decisive; lawyers of eminence played with it as though it were one of the choicest morsels from the tree of knowledge; it was the last word in gaging the flow of water. And there was reason for such an estimate of its value at the time.

James Bicheno Francis was then easily the leading hydraulic engineer in the United States, with perhaps not over half a dozen of the species in the whole country. Grappling as a young man with the problem of insuring their lawful quantities, day by day, to each of the seven "Proprietors of the Locks and Canals on Merrimack River," at Lowell, Massachusetts, out of the common trough or canals which fed them collectively, he may be said to have been the first one who thus brought order out of the disorder which that communistic distribution of water—naturally accompanying the American system of power distribution canals for manufacturing purposes, and now passing away in favor of the electrical distribution of power—always brings with it. For the purpose named he instituted, about 1850, the series of hydraulic experiments described in his book entitled Lowell Hydraulic Experiments; and he did this with all the accuracy obtainable at the time and place that has been named.

From another point of view than just described were his experiments of a new order of importance. If any one will consult Weisbach's Experimental Hydraulik, or the later editions (1855-60) of Weisbach's Mechanics, he will be surprised at the Lilliputian dimensions of the apparatus then in vogue as the basis of engineering knowledge for use in the practice of hydraulics. Thus Weisbach's experimental reservoir had an area of 1.35 sq. ft.; and his ajutages were ordinarily about three hundredths of a foot in width, or diameter. Of course, we know that Atwood's machine, of extremely moderate dimensions, will measure the force of gravity exercised by the globe which we inhabit; but it requires more confidence in the "horse sense," no less than the technical ability of hydraulic engineers, than is possessed by the average mill owner or his agent to give him confidence in the work of the engineer he employs, should that engineer base it on experiments such as inspired Julius Weisbach or his immediate disciples. So that the experiments of Francis, conducted out of doors on a scale commensurate with their importance, at the lower locks of the Concord River, came to the interested "Proprietors" and others as a refreshing and new conquest of mind over matter. They were much more reliable because made on a natural scale; exact, as every one could appreciate, from the care taken in making the experiments and the computations following the experiments, and thoroughly reliable.

At that time arose the expression, "made with a standard weir," which has remained alive to the present day, although, as will presently be seen, there was no propriety whatever for calling any weir a "standard." The only standard water-gaging apparatus is a tank or reservoir. Weirs, orifices, venturi tubes and meters, and other water-gaging apparatus and methods, can only become truly rated by comparison with tank measurements, and thus thereafter competent to give reliable service. Such comparisons, moreover, establish the *degree* of reliability of the several methods that have been subjected to comparison, and from this point of view the weir has for many years been falling into deserved disrepute.

To treat the matter somewhat chronologically, there is the article in *Engineering News* for November 10, 1898, by the present writer, protesting against the multiplicity of formulæ that sharp-edged weirs and orifices, and present methods of observing heads upon them, bring in their train; and suggesting that observations be taken *at* the weir or orifice, and that weirs and orifices cut "in a thin plate" be abandoned.

In the Transactions of the American Society of Civil Engineers for 1914, the discussion on the paper of R. R. Lyman, Mem.Am. Soc.C.E., brought out clearly the number of methods there were in use to measure "head upon the weir," and their idiosyncrasies.

---

[1] Hydraulic Engineer, 2 Wall Street. Past-President, Am.Soc.C.E.

[2] "M. D. Bernoulli mà souvent dit de me défier de toutes ces formules compliquées; il croit que la nature est trop simple pour y mener; et que si on en trouve, c'est qu'on a fondé ses calculs sur des fausses hypothèses."—R. Wolf, Biographien zur Kulturgeschichte der Schweiz, Band 3 (1860), p. 176.

Abstract of a paper to be presented at the Spring Meeting, St. Louis, May 24 to 27, 1920, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. All papers are subject to revision.

These several methods go far beyond any forethought of the pioneer experimenters in that sort of work, and definitely confirm the rule that when any one formula is to be used to compute weir discharge, the weir and methods of taking observations of flow over it must imitate with slavish exactness the construction of the weir and methods of taking observations that were followed in constructing the selected weir formula, a matter of annoyance or difficulty as a rule.

Fteley and Stearns, for example, Trans.Am.Soc.C.E. for 1883, p. 5, say: "It is, however, almost impossible to cover all cases that may occur in practice."

Bazin, in his 1890 article, Part I, for that year, of *Annales des Ponts et Chaussées*, p. 4, and elsewhere, says that to attempt to experiment on all cases possibly to be met with in practice (instead of setting up a standard form to be used in such work) must be pronounced impracticable. And in his 1898 article, Part II for that year, p. 161, he says: "Each type of weir would therefore require a special study; and face to face with a complexity like this, one must abandon the idea of establishing formulæ for general application."

R. E. Horton, Trans.Am.Soc.C.E., 1914, p. 1300, tells us that "of the making of many formulæ there is no end." Also, p. 1326, "If Francis had used higher and lower heads, he would have discovered that no one equation of the form he uses, $Q = mh^n$, can fit accurately a series of experiments on weirs of the type herein considered."

Hamilton Smith[1] saw this, and very likely Francis did, for Francis was very particular to state that the formulæ he gives must only be used between stated limits of head, and only upon fulfillment of other stated conditions of weir construction and operation.

Finally, in the discussion on the Paper by Floyd A. Nagler, Trans.Am.Soc.C.E. for 1918, the subject now under consideration was again debated by interested hydraulic engineers, the present writer among the number; and the status of the whole question was summed up by F. P. Stearns, Mem.Am.Soc.C.E., himself an experimenter on weirs of more than 40 years' experience, when he said with startling, yet righteous, precision that "in the present state of the art the weir is not an accurate instrument for the measurement of water."

An Advance in the State of the Art Believed to Have Been Now Attained

After this survey of the state of the art, and to give a résumé of what this article will endeavor to establish, it may not be improper to say at once that it treats of a weir whose discharge is represented by a straight-line formula from 0 up to 9.55 cu. ft. per sec. per ft. in length of weir, and thus continuing, presumably, indefinitely beyond that quantity. Its equation is $Q = 5.50d$; d being the difference of two observations of water height or pressure; the one taken just upstream from the weir (taken so as to be automatically corrected for "velocity of approach," if one pleases, or corrected by computation before being used in the above formula, if preferred), and the other taken *at* the crest. In both cases d is obtained by measuring the elevation of a water surface in a pail by means of a hook gage, or otherwise as desired. This *difference* of pressures may also be obtained by means of one of the many devices already invented and on the market for measuring differences of pressure, in which case the register may indicate mechanically the quantity passing at any moment, sum it up for any given period of time, portray it graphically on a chart, or simultaneously do all three of these recording operations.

It will be observed that the process just described is not open to the criticism of R. E. Horton, mentioned above, who said: "No one equation, of the form he (Francis) uses, $Q = mh^n$, can fit accurately a series of experiments on weirs of the type (sharp-edged weirs) herein considered." It does this, moreover, with the added simplicity of making the exponent n equal to 1.

And the reason it does all this is because it is carried out with a weir that is not a "sharp-edged weir," the type that has rested like the incubus of an evil spirit upon the minds of all hydraulicians for full 200 years, ever since the Marchese G. Poleni first wrote about weirs in De Motu Aquae Mixto, Patavii, 1717. Bazin and others have thought that to attempt to set up a standard form of weir for measuring water was visionary, in view of the many variations in weir discharge so easily brought about. But this very thing was one of the objects of the experiments now under consideration, and time alone will tell whether or no it has not after all been accomplished.

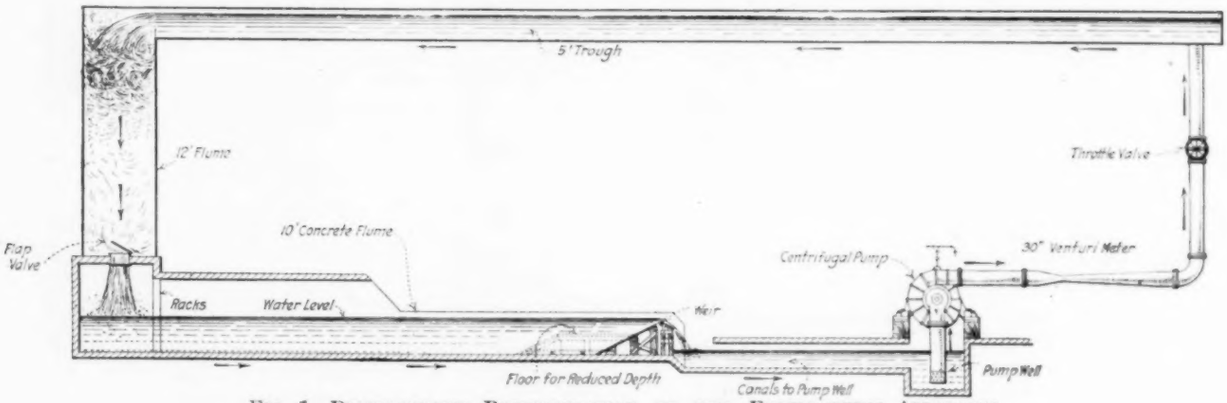


FIG. 1 DIAGRAMMATIC REPRESENTATION OF THE EXPERIMENTAL APPARATUS

The Power Test Code Committee of The American Society of Mechanical Engineers, and Engineering Foundation

After this much said in anticipation, we will go back now to a chronological order of events. The American Society of Mechanical Engineers, having appointed a Committee to draft a revised form of Power Test Code in 1917, and invited the three other Founder Societies to appoint advisory committees to the same end, the writer was appointed as one such advisory member. It thereupon very soon appeared that the matter of weir measurements and of their accuracy was in a most deplorable state of confusion. On the proper representations having been made to Engineering Foundation that a new set of experiments on weir discharge were liable to lead to a considerable advance in knowledge in this branch of applied science, it made an appropriation for that purpose, to be expended by the writer.[1] The experiments about to be described have been the result of these preliminaries.

[1] Hydraulics, John Wiley & Sons, 1886.

[1] Acknowledgment is also here gratefully made to the President and Faculty of the Massachusetts Institute of Technology, especially to Prof. Edward F. Miller; to Wm. F. Uhl, B. S. Rose and H. L. Woodruff of the office of Chas. T. Main and to Mr. Main; to Chas. W. Sherman, H. P. Eddy, Jr., and others of the office of Metcalf & Eddy and to their principals, all of Boston; and to Builders Iron Foundry, of Providence, R. I.; for most efficient aid rendered in various ways at various stages in the conduct of the experiments herein described; and done in a way that amounted to a contribution to enable all the described work to be done.

THE HYDRAULIC LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The place selected for conducting the experiments was the Hydraulic Laboratory of the Massachusetts Institute of Technology. This laboratory had barely been completed when the United States entered the World War, and all the energies of the Institute thenceforth had been devoted to its notable war work to a degree that left improvement in and perfection of its school apparatus rightfully a secondary consideration. As a consequence, the hydraulic part of the laboratory on closer study was shown to have many remediable defects, which, no doubt, will be eliminated in course of time. These, again, affected both the difficulty of making the contemplated experiments and the precision at which results could be attained. But the choice had been made, many reasons existed for persevering in the place where the work had been planned, and thus the experiments were completed as they had been projected.

For a description of the Institute Hydraulic Laboratory reference is made to an account in the March, 1918, number of the *Journal* of the Boston Society of Civil Engineers, by Prof. Geo. E. Russell of the Institute. Briefly stated, the apparatus used in the present experiments and shown diagrammatically in Fig. 1 consisted of a 350-hp. Ball angle-compound engine, 240 r.p.m., direct-connected to a 30-in. Worthington centrifugal pump, having some 48 cu. ft. per sec. maximum capacity at 40 to 45 ft. lift. This pump takes its suction from a system of canals under the floor of the basement, which are or may be connected with the Charles River Basin.

Right here arose one great obstacle in the making of these hydraulic experiments. The canals that have been named at times took to "surging," causing oscillations of the pump-well surface, and these, in turn, were transmitted through the pump and could plainly be seen at the upstream end of the discharge pipe. They were also indicated by the 30-in. venturi meter set in line of the discharge pipe, next downstream from the pump. Two whole afternoons' work were rendered useless from this cause. But by experience and careful work any gross effect from this cause could be avoided.

The discharge pipe delivered into a riveted trough of steel, 5 ft. by 5 ft. and about 135 ft. long, at some 40 ft. higher elevation than the pump. In it was set the 16-in. by 5¼-in. venturi meter used to measure quantities smaller than about 8 cu. ft. per sec. (Sept. 25, 26 and 29), the larger quantities being measured by the 30-in. meter already spoken of.

Both these meters were read by means of mercury straight-tube manometers, as made by the builders of the meters. The scale of these manometers was based on a coefficient of discharge for the meters of 0.99. These were the facilities at hand, or readily procurable and installable; and though not so precise as a tank measurement would have been, were sufficiently so for the pioneer work to be done. It is not often, as yet, that one can get a reservoir to hold 46 cu. ft. per sec. for the period of a hydraulic experiment; and in the opinion of the writer the venturi meter is the next best thing. It certainly was at the hydraulic laboratory that had been selected for making the present experiments.

That the venturi meter is of a high order of accuracy has been shown by a compilation by the writer for the Power Test Code Committee of all attainable relevant experiments made with it during its existence of 30-odd years. A very significant series of tests, made by F. H. Shaw, Mem.Am.Soc.C.E. of a meter at Lancaster, Pa., show an average variation of 0.036 of 1 per cent for 44 tests covering a period of eight years.

To return to our present meter observations: The scale of the manometers read tenths of cubic feet per second; and hundredths could readily be estimated on both of the meters used.

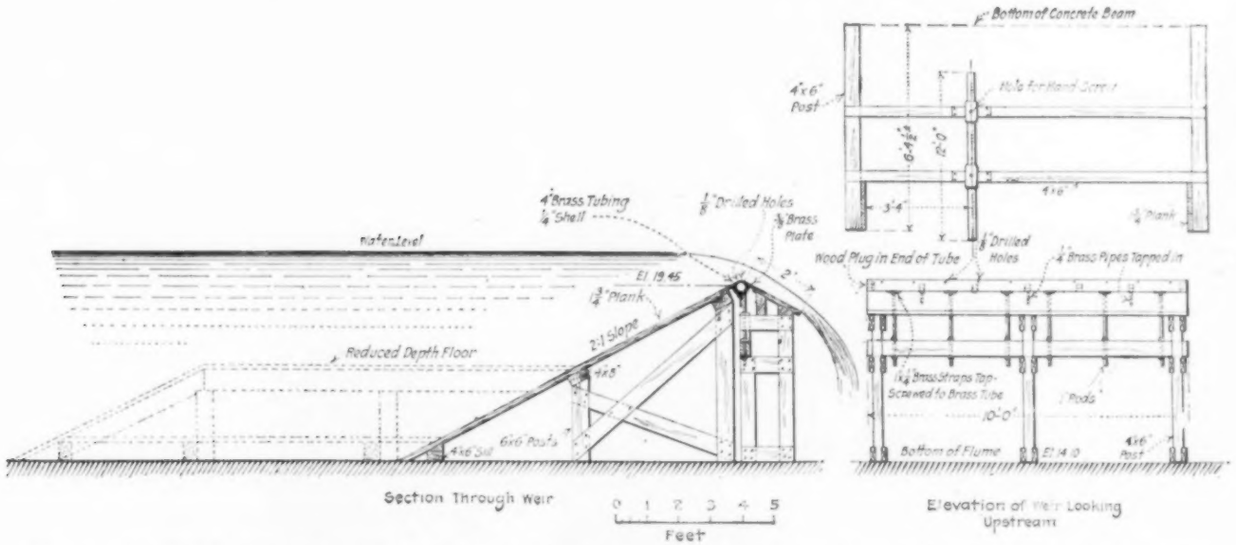


FIG. 2 THE NEW WEIR (THE SURFACE CURVE OF WATER DISCHARGING OVER THE WEIR IS DRAWN FROM MEASUREMENT.)

From the 5-ft. trough the water fell into a vertical flume or wheel pit 12 ft. in diameter, made of riveted steel and 22.5 ft. high; and through a wooden adjustable flap valve in the floor of this flume, fell into a concrete tail-race pit, which, through racks and gridiron-valve gates, discharged into the concrete channel about 72 ft. long that led to the weir to be tested. The discharge of the weir fell back into the system of canals which fed the centrifugal pump, thus completing the cycle actuated by the Ball engine and pump.

The free discharge of the 5-ft. trough into the 12-ft. vertical flume could be rendered somewhat less turbulent by keeping the flume-water elevation as high as possible without waste, this again being crudely controllable by means of the wooden flap valve in the floor of the vertical flume. But this whole arrangement and the free discharge through the flap valve into the tail-race pit below were imperfect arrangements, acknowledgedly only temporary in character, and were the cause, together with the "surging" of the pump-well water above referred to, of many of the difficulties experienced in making these experiments. They also were the principal cause of most of the lack of precision that remains and is inherent in the final results.

It would have been gratifying to remove some or all of these crudities, and also to greatly extend the scope of the experiments, but the limits of the appropriation available forbade going beyond the work that was actually done.

To vary the discharge, the pump operating at a uniform speed as governed by a flywheel governor, and the boiler pressure also being fairly constant, a throttle valve in line of the pump dis-

charge pipe was used. When the small 16-in. meter set in the 5-ft. trough was in action, the quantity and constancy of the flow leading to the meter and the efficient action of the pump, in spite of the small quantities lifted, could be regulated by opening a waste valve out of the pump discharge pipe. To a minute extent, certainly sufficiently to remove all air from the pump discharge pipe before it reached the 30-in. meter, the same office was performed by keeping in action a 2-in. steam siphon, set at the extreme upstream end of the pump discharge pipe and ordinarily used to exhaust air from the pump before starting it.

The concrete channel above referred to was nominally and almost exactly 10 ft. wide, and had at its downstream end a sharp-crested weir whose crest was about 5.35 ft. above the bottom of the channel. The new form of weir was so designed that it could be built over and around the old weir, and again removed without injury or displacement of what was found on the premises, and with its crest at nearly the same elevation above the bottom of the concrete flume.

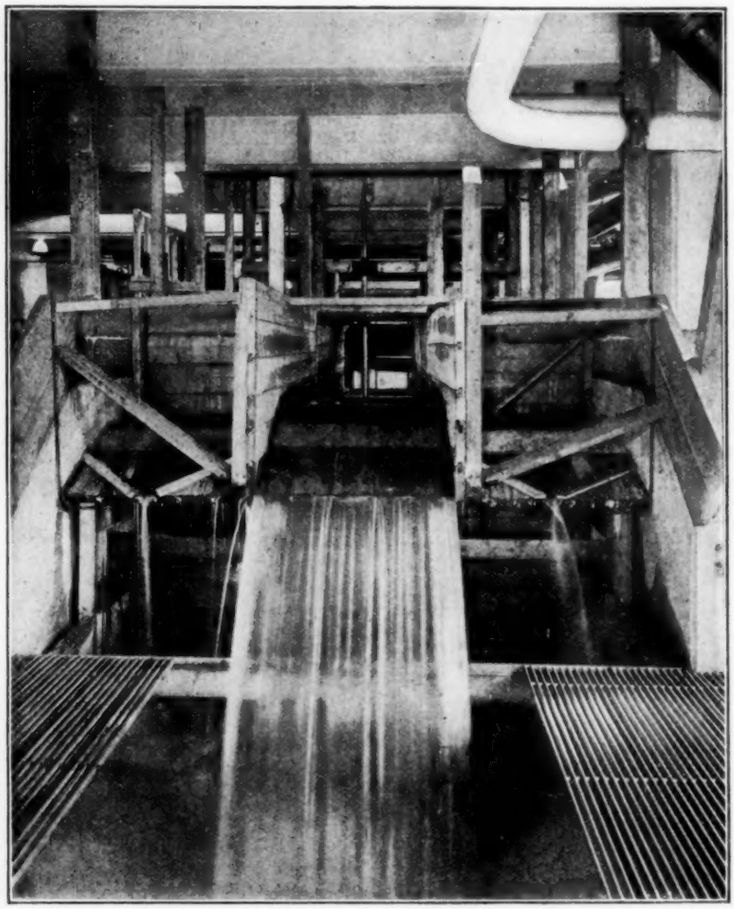


FIG. 3 THE SHORT WEIR IN ACTION

Leakage on each side could be measured either by the new formula; or by catching it in a pail and weighing the amount caught in an observed period of time; or by both these methods simultaneously.

THE NEW WEIR

In its general outlines, the new weir, Fig. 2, was described in the *Engineering News* 1898 article above referred to. More particularly was it forecast in the Trans.Am.Soc. C.E. discussion of 1918 that has been named. So here was a case of an invention, or vision, if one pleases, in practical hydraulics that had to wait 20 years in the brain of the engineer for lack of public or private facilities to test it. An attempt to experiment as has now been done was made some 10 years ago, but was frustrated by the writer being informed by the manager of a richly endowed institution that its funds were only available for research in sciences that had no practical applications. The wonder is that any progress at all is made in this most useful of the arts. One endowment only exists as yet for the development specifically of applied science or engineering—the Engineering Foundation, begun by Ambrose Swasey, of Cleveland, Ohio; and it was most gratifying to the writer to have been allowed to endeavor to illustrate some of the work of which such an endowment is capable.

The fundamental idea followed in the design of the new weir was to have the water to be measured conducted over the weir in a gentle manner, and so to have it flow smoothly and regularly from the time it first encounters the weir construction until it leaves it. Instead of allowing the body of water to impinge with more or less violence, according to the velocity with which it approaches the weir, against a perpendicular wall in its path (the upstream face of the ordinary weir) it is gently led to the crest by a 2:1 slope. Instead of striking or being torn over a sharp edge at the crest, the crest is made in the form of the arc of a circle; and instead of bothering about air under the nappe, the nappe is supported on another 2:1 slope downstream from the crest. Moreover, the crest is made hollow, so that observations of the pressure, or lack of full pressure, whichever the water may elect to exercise, can be taken *at* the crest, not at a distance upstream from the crest varying according to the fancy of the experimenter.

If the quantity passing the weir turns out to be a function of this observed pressure, well and good. If not, we will see what virtue there is in the *difference* of water elevations or pressures, the one taken upstream from the weir and the other taken by means of the hollow weir crest.

The difference referred to proved to be the sought-for solution of the problem at hand, and hereafter it alone will be closely considered. A United States patent has been applied for, covering the weir construction herein described.

The orifice in the side of the concrete flume conducting water to the hook-gage pail for measuring water elevations upstream from the weir was made flush with the flume side, at a point 13.9 ft. upstream from the weir crest center, and 1.68 ft. below it in elevation.

Furthermore, to connect the water passing over the weir with the hollow of the weir crest, a series of $\frac{1}{8}$-in. holes were carefully bored through into the latter. This was done by first tapping in a solid brass plug, and then boring a hole $\frac{1}{8}$ in. in diameter through this plug. A natural inclination would be to bore these holes at right angles to the surface curve of the water, but as this varies with the quantity passing the weir, such an inclination is impracticable. There are only two other natural directions for such piezometer holes—either vertical, or at right angles to the upstream slope of the weir; and if the latter, naturally at the line of tangency of that upstream slope and the arc of the weir crest. The vertical holes are called "Orifices No. 1" and those perpendicular to the 2:1 slope, "Orifices No. 2". The original intention of the writer had been to make the crest tube so that it could be revolved around its horizontal axis, and thus find the best position of the piezometer orifices, but a cumbersome and unduly expensive experiment like this was at once abandoned, and in view of the success already attained, may now be disregarded by engineers.

Both kinds of piezometric orifices were tried, and the last-named proved much the superior for general use.

To vary the velocity of approach a false bottom was put into the channel for some of the experiments. These will be designated as having been made with "reduced depth" and others with "full depth."

The diagrammatic drawing, Fig. 1, will make clear the description of the weir test apparatus given in the foregoing paragraphs.

To increase the quantity per foot in length of weir, the avail-

able capacity of the pump was in many of the experiments made to pass over only about 3.3 ft. of the length of weir, as shown in Fig. 3, while other series of the experiments used a weir about 10 ft. long.

As these experiments had a practically useful end and aim —the establishing of a commendable method of weir measurements—end contractions were ruled out from the very beginning. They are of no use, ordinarily, and only complicate the situation. Even in the few cases of working with sharp-crested weirs, when side contractions are introduced so as to cause greater depths upon the weir with a diminishing quantity of water, or so as to cause a selected formula to apply, they could be avoided at the cost of a very little extra carpenter work. But with the straight-line formula about to be established and valid from zero up to the maximum found by the experiments herein described, there is no occasion whatever to change the length of the weir so as to accommodate the quantity of water about to pass it, and side contractions become either foolish or pseudo-scientific. None of the following experiments includes them.

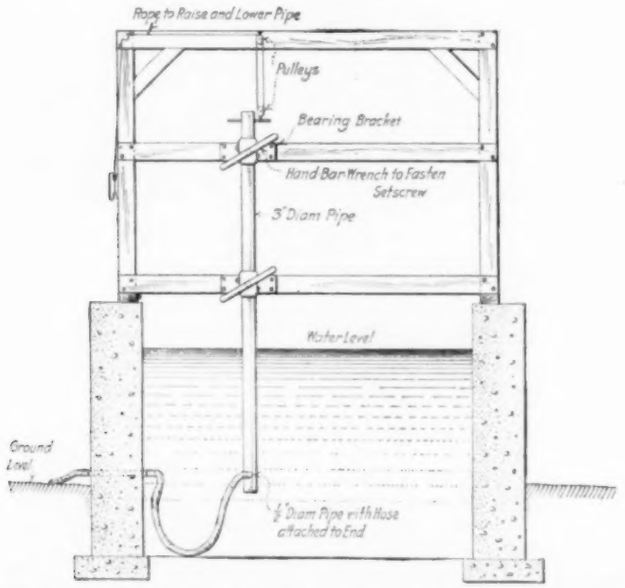


FIG. 4 APPARATUS TO OBSERVE THE WATER ELEVATION UPSTREAM FROM THE WEIR, AUTOMATICALLY CORRECTED FOR "VELOCITY OF APPROACH"

AUTOMATIC CORRECTION FOR VELOCITY OF APPROACH

In the photographic view of the new weir in action, Fig. 3, a vertical brass pipe dipping into the water will be noticed in the background, which is also shown in detail in Figs. 4 and 5. This was intended as a means of observing the water elevation upstream from any part of the weir, automatically corrected for velocity of approach, by taking in the water pressure through a pitot orifice pointing upstream and transmitting it to a hook-gage pail in the usual manner from out of the downstream side of the vertical tube. A pointer above water, parallel to the pitot tubular orifice, which should point upstream, insures its correct position. Our experience leads us to advise that the vertical tube be not used as a reservoir, but only as a support for the pitot orifice.

The tube is held in its guides by two clamp screws, and may readily be set so as to bring the pitot orifice in the locus of mean velocity as it may be judged or found. In these experiments it was set at 6/10 depth of water, and ⅓ the width of the channel from either side. A scale of feet and tenths on the tube, reading up from zero at the pitot orifice, and aided by another scale or gage painted on the side of the concrete flume, reading up from zero at the flume bottom, readily permitted this. The apparatus is mounted on two beams crossing the water channel and at a convenient height above it.

This apparatus exists as yet only in theory and should be experimented with at the first favorable opportunity, because on drawing the water out of the flume at the close of our experiments a broken and leaky joint was discovered in the rubber pipe that carried the water pressure from the vertical tube to the hook-gage pail, so that the readings taken proved unreliable, or of no record value whatever.

NEED AND SCOPE OF FURTHER EXPERIMENTS

A crew of six men, including three observers, with a captain, had been working with the apparatus from September 10 to October 3, 1919, and it was with great regret that the writer gave the order to dismantle the weir because so much remained to be discovered.

But October 3 was Friday, the last day of the week for us. The laboratory closed at 5 p.m., and on Monday the regular school term commenced. The appropriation for the work was nigh exhausted and it was high time we quitted the premises.

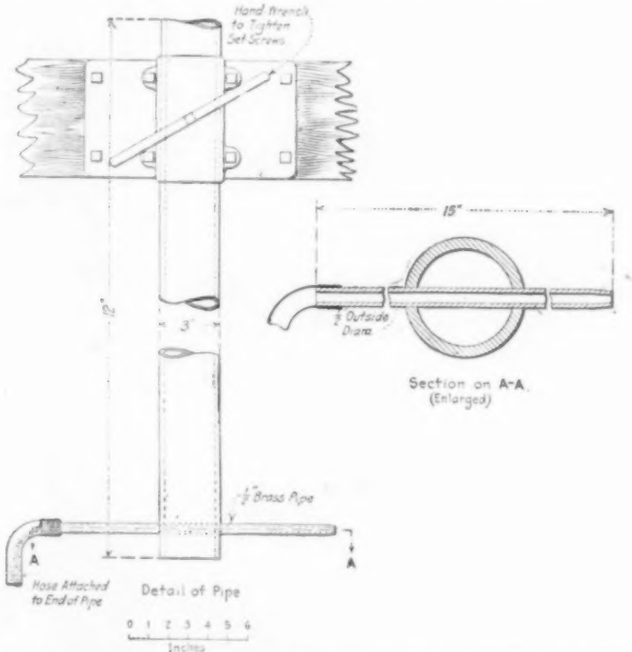


FIG. 5 DETAILS OF APPARATUS SHOWN IN FIG. 4 TO OBSERVE THE WATER ELEVATION UPSTREAM FROM THE WEIR

There was, first of all requiring further investigation, the effect of the radius of the weir crest. Bazin had experimented on a weir composed of two 2:1 slopes meeting at a sharp angle and with a little pipe to indicate pressure "under the nappe," *let into the body of the weir slope upstream from the crest.* This can not enlighten us very much, but is the nearest approach to our experiments known to the writer.

Our weir crest had a radius of 0.198 ft., and the outside surface was hard and smooth oil paint.

No doubt the radius of the weir crest is a factor in the application of the formula found for weirs of the construction shown in this article, but it remains for other sets of experiments to reveal the limits and detailed effects of this radius.

THE EXPERIMENTS

With these preliminary statements, the record of the 40 experiments made is given in Table 1. Four of them have been marked doubtful on account of actual or supposedly defective observations and all those made September 9 and 30, also part of those on September 25, had to be rejected as worthless on account of the previously mentioned violent "surging" of the water discharged by the pump.

A separate set of gagings was made October 3 to compare the indications of the Institute's sharp-edged weir with the Institute's 30-in. venturi meter. Owing to the fact that this meter is set in line of the pump discharge pipe, only 12 ft. distant from the pump, it had been a question whether at that short range it would meter accurately, and the experiments of

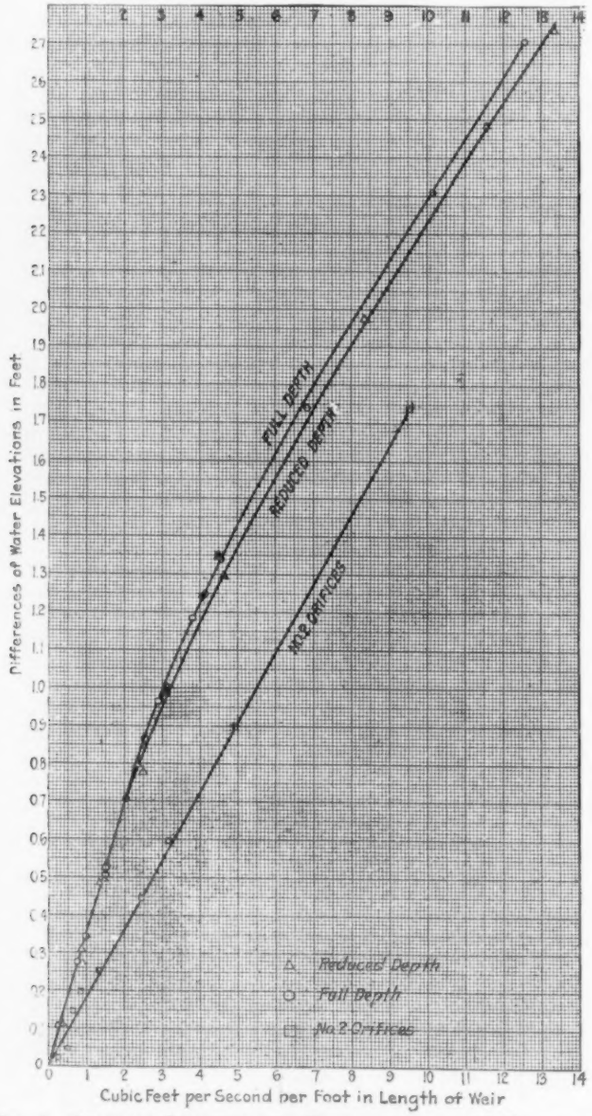


FIG. 6 DIAGRAM SHOWING THE RESULTS OF THE 40 EXPERIMENTS MADE

October 3 were made for the purpose of answering this question. The system for observing head on the weir, available, was that known as the Fteley and Stearns method. A metal plate was set in the side of the concrete flume, flush with it, and an orifice in this plate in the present instance was situated 6.8 ft. upstream from the crest and 1.68 ft. below it in elevation, connected with a hook-gage pail in the usual manner.

RECORD

Pump started about 12.30 p. m., discharging 30 cu.ft. per sec. at 1 p. m. All quantities corrected for velocity of approach.

	WEIR	METER
	Cu. Ft. per Sec.	
Oct. 3, 1919, 2.05 to 2.10 p. m., both inclusive	38.13	38.30
2.50 " 2.55 " " " "	30.33	31.25
3.50 " 3.55 " " " "	17.91	18.80
4.40 " 4.45 " " " "	11.73	11.00

Having in mind the imperfections of the whole test apparatus from the canals in the basement, through the pump, riser, 5-ft. trough, 12-ft. vertical flume, wooden flap valve, into the 10-ft. concrete flume, and over the weir, as already mentioned, it is quite possible that 38.13, 30.33, 17.91 and 11.73 cu. ft. per sec. were passing the weir on the average for 5 min., while 38.30, 31.25, 18.80 and 11.00 cu. ft. per sec. were being discharged by the pump on the average during the same 5 min. The difference could very well represent rise or fall in the mean elevations of the water in either the 5-ft. trough, the 12-ft. vertical flume, or in the 10-ft. concrete flume, or in two or more of these containers simultaneously.

The comparison which was made, alone, does not argue for superior exactness of gaging by either the weir or the meter —that must be determined by tank tests made with the two separately. It only showed that neither was materially inexact. And we know from data that have been given, that next to tank tests the venturi meter is an exact method for measuring water.

And with the result placed in evidence, that No. 2 orifices act according to the straight-line equation—

$$Q = 5.50d \text{ in English units}$$
$$Q = 1.675d \text{ in metric units}$$

this paper might fitly close.

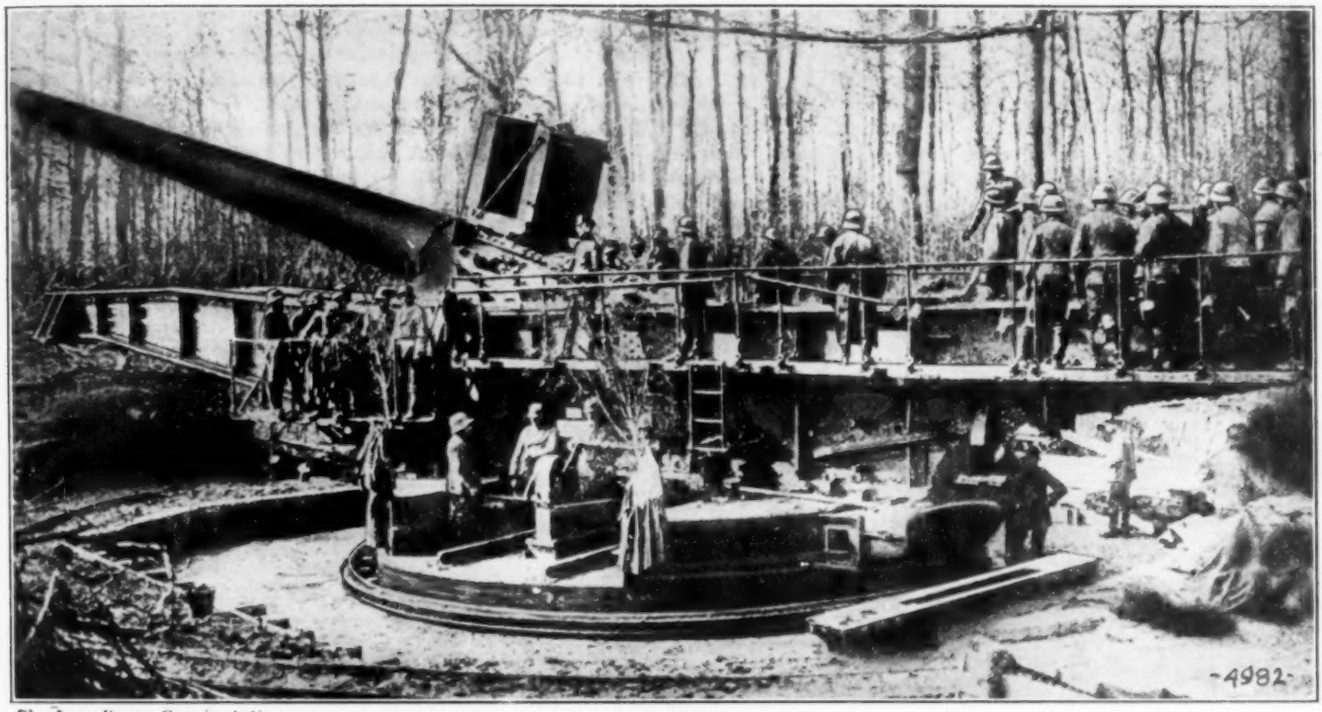
Fig. 6 shows the results of Table 1 in graphic form.

(Continued on page 132)

TABLE 1 EXPERIMENTS WITH THE HERSCHEL WEIR

Date 1919	Length of Run P. M.	Velocity of approach, ft. per sec.	Depression = Piezometer height (corrected for velocity of approach) less weir indication. As measured	Depression = Piezometer height (corrected for velocity of approach) less weir indication. Corrected for v. of a.	Quantity per ft. of weir length, cu. ft. per sec.
Sept. 10[1]	2.45-2.50	0.70	1.332	1.340	4.53
	4.00-4.05	0.58	1.182	1.187	3.82
	4.30-4.35	0.48	0.991	0.995	3.06
	4.55-5.00	0.33	0.700	0.702	2.03
Sept. 11[1]	1.50-1.55	0.24	0.522	0.522	1.49
	2.20-2.25	....	0.347	0.347	0.95
	2.50-2.55	....	0.279	0.279	0.75
	3.20-3.25	0.24	0.508	0.508	1.47
	3.55-4.00	0.45	0.962	0.965	2.87
	4.45-4.50	0.62	1.240	1.246	4.07
Sept. 15[2]	2.15-2.20	1.24	1.319	1.349	4.48
	3.00-3.05	0.92	1.001	1.014	3.14
	3.50-3.55	0.72	0.790	0.798	2.34
	4.25-4.30	0.50	0.529	0.533	1.53
	4.55-5.00	0.30	0.305	0.307	0.85
Sept. 17[3]	2.30-2.35	1.62	2.683	2.723	12.53
	3.05-3.10	1.39	2.279	2.309	10.18
	3.40-3.45	1.00	1.725	1.741	6.87?
	4.20-4.25	0.63	1.229	1.237	4.15?
	4.50-4.55	0.40	0.864	0.868	2.57
Sept. 18[4]	1.55-2.00	2.87	2.603	2.733	13.38
	2.30-2.34	2.60	2.374	2.484	11.53
	3.05-3.10	2.01	1.915	1.977	8.31
	3.50-3.55	1.28	1.269	1.294	4.63
	4.35-4.40	0.75	0.773	0.782	2.45
Sept. 25[4]	3.10-3.15	0.40	0.478	0.482	1.33
Sept. 26[4]	1.43-1.45	0.47	0.491	0.495	1.42
	3.05-3.10	0.25	0.265	0.265	0.71
	4.10-4.15	0.13	0.120	0.120	0.36?
	4.40-4.45	....	0.101	0.101	0.24?
Sept. 29[5]	3.15-3.20	0.42	0.249	0.253	0.13
	3.55-4.00	0.29	0.194	0.195	0.087
	4.25-4.30	0.18	0.149	0.149	0.051
	4.45-4.50	0.18	0.042	0.042	0.049
	5.05-5.10	0.08	0.022	0.022	0.021
Oct. 1[5]	1.30-1.35	2.22	1.658	1.738	9.55
	2.10-2.15	1.90	1.189	1.249	6.91
	3.10-3.15	1.34	0.865	0.895	4.93
	3.45-3.50	0.92	0.581	0.593	3.14
	4.20-4.25	0.73	0.438	0.447	2.42

[1] Long weir, full depth.
[2] Long weir, reduced depth.
[3] Short weir, full depth.
[4] Short weir, reduced depth.
[5] Short weir, reduced depth, No. 2 orifices.



The Long-Range Gun in Action

The German Long-Range Gun

An Account of the German Super-Gun Bombardment of Paris from the Forest of Gobain, 70 Miles Distant, in the Spring of 1918, Together with Authentic Details Regarding the Design of the Gun, Carriage, Emplacement and Projectile

By LIEUT.-COL. H. W. MILLER,[1] U. S. A.

AT 7.15 on the morning of March 23, 1918, just two days after the Germans opened their offensive against the British 5th Army before Amiens, the people of Paris were startled by an explosion of something that had fallen on the Quai de Seine. The explosion was of such magnitude that it could be heard over practically the whole of Paris. Fifteen minutes later there was another explosion of the same magnitude, but this time closer to the Seine, on the Rue Charles V; fifteen minutes later another explosion occurred on the Boulevard de Strasbourg near the Gare de l'Est. Until that time Paris had never been bombarded except from airplanes and zeppelins, and the first thought of the people was that they were being bombarded from some new type of aircraft that was being operated at such a height that it was practically invisible.

The explosions continued to occur throughout the morning at very uniform intervals of 15 min., and by evening 21 explosions had occurred at the places shown in Fig. 1. After the first few explosions, between seven and eight o'clock in the morning, business in Paris practically ceased. Stores were closed and part of the Metro system ceased to operate; ticket offices in some of the railway stations were closed, and great numbers of people could be seen walking the streets looking skyward trying to locate the planes that were dropping the supposed bombs.

The Bombardment of Paris

Information of the extraordinary bombardment was telephoned and telegraphed over practically the whole of France within a few hours and was received everywhere with amazement. After a few hours of the first day a sufficient number of the fragments of the exploding agent were collected by officials in Paris to identify it as a projectile being fired from a gun, rather than a bomb being dropped from an airplane. By noon representatives of the Heavy Artillery Section of the Ordnance Department, located at Tours, had made preliminary calculations in response to telephone instructions from Paris giving the probable muzzle velocity at which a projectile would have to start in order that it might travel from a few kilometers within a point of the German lines nearest Paris to the center of Paris. Inquiries were made likewise of the Section as to the possibility that these projectiles could actually be coming from a gun within the German lines. The reply was that the probable muzzle velocity of the projectile, if it was actually being fired within the German lines, was not less than 4500 ft. per sec. No such muzzle velocity had, to their knowledge, ever been realized, but with a gun of sufficient length and with a powder burning at a satisfactorily low speed it was considered quite possible for the projectiles to be fired from within the German lines. By the end of the first day officers of the French, as well as the American, armies were quite certain that the projectiles were being fired from a newly designed long-range gun located within the German lines, and operating at a probable range of 110 km. (68.8 miles).

During the next few days some interesting theories were advanced in the various newspapers. In one case it was maintained that the projectiles which arrived in Paris were being fired from another much larger projectile, which actually served as a gun. This larger projectile was said to have been fired from a gun within the German lines, and upon attaining a certain height a charge of powder within the larger projectile was automatically ignited, firing the smaller one to a much greater distance. The theory that the projectiles were being fired from guns concealed in abandoned quarries or in heavily wooded regions near Paris received considerable credence, and diligent search was made of

[1] Office of Chief of Ordnance, Artillery Division, Washington, D. C. Released for publication by the War Department, Office of the Chief of Ordnance, and contributed to MECHANICAL ENGINEERING.

all such places to be certain that it was not true. A third theory was that the projectiles were being fired from a pneumatic gun located within Paris.

A plotting of all the bursts for the first day showed results that were very puzzling. If the guns were being operated at comparatively short distances, the only way to account for the tremendous dispersion was on a basis of actual laying of the gun for different objectives. This theory did not seem plausible, however, because if the gun was actually laid on given objectives, these objectives were of relatively small importance. If, on the other hand, the projectiles were being fired from a gun at a great distance, it was

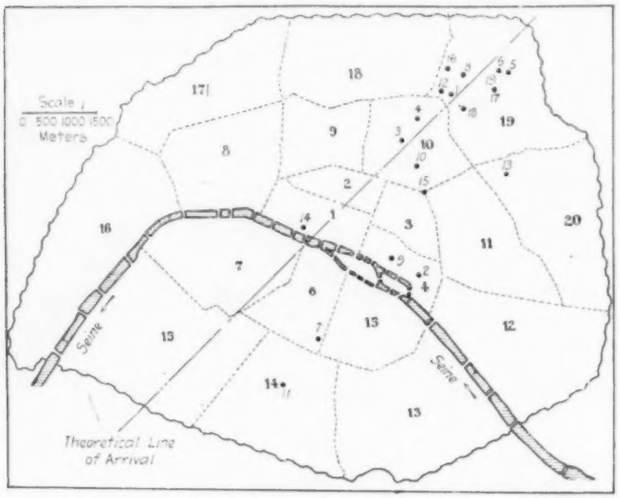


FIG. 1 MAP OF THE CITY OF PARIS, SHOWING POINTS OF BURSTS ON FIRST DAY OF LONG-RANGE BOMBARDMENT (MAR. 23, 1918) IN THE ORDER OF THEIR ARRIVAL

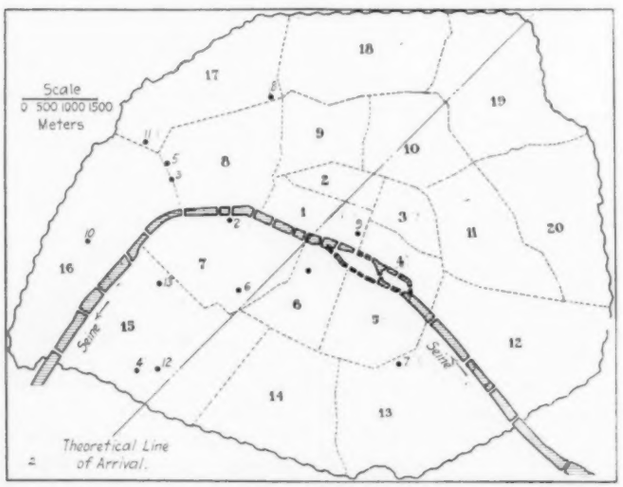


FIG. 2 MAP OF THE CITY OF PARIS, SHOWING POINTS OF BURSTS ON LAST DAY OF THE LONG-RANGE BOMBARDMENT (AUG. 5, 1918) IN THE ORDER OF THEIR ARRIVAL

seen at once that the dispersion was so great as to make it practically impossible to hit with any certainty any objective much smaller than that portion of Paris within the walls. It was noticed that the dispersion in direction, that is, to the right or to the left of the line on which the projectiles were arriving, was comparatively small, while the dispersion in range, that is, over or under the probable point at which the projectiles were supposed to arrive, was very great. Examination of the map, Fig. 1, shows that on this first day, when the gun was new, the average dispersion in range was very small compared with the dispersion on later days when the gun became worn.

Evidence received later indicates that at the end of this first day's bombardment the first gun was about half worn out. Eighteen projectiles had fallen within the walls of Paris, and three outside; fifteen people had been killed and thirty-six wounded. The destruction of property had been comparatively small. By "comparatively" it is meant that the destruction was small in comparison with that wrought by the 100- and 300-kg. airplane bombs. Whenever the projectiles landed in the street or in an open plot of ground, the hole made was seldom more than from 12 to 15 ft. in diameter, and from 4 to 6 ft. in depth. When the projectiles struck buildings it was not unusual to have them explode in the interior without showing any serious signs of damage on the outside.

On the 24th of March thirteen projectiles fell within the walls of Paris and nine without, killing eleven people and wounding thirty-four. On the 25th, four projectiles fell within the city and two without. This was the end of the first gun. It was worn out, and no more firing was done until the 29th, when the second gun began its work.

Search of the files of the French War Office revealed the fact that full drawings and plans had been on hand for quite a long time for such a gun as the Germans were probably using. These specifications had been submitted a number of years before and had been discarded because of the excessive expense and the tremendous difficulties involved in manufacturing such a gun. It was considered likewise by those who had turned down the specifi-

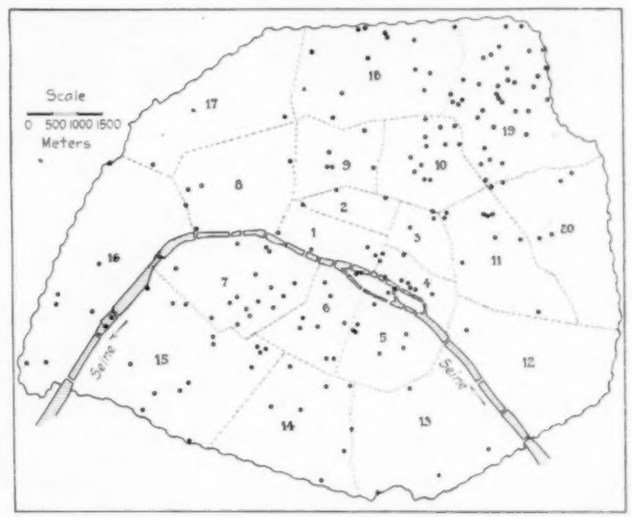


FIG. 3 MAP OF THE CITY OF PARIS, SHOWING POINTS OF BURSTS OF THE 183 PROJECTILES THAT FELL WITHIN THE WALLS IN 44 DAYS OF BOMBARDMENT

cations that the value of such a gun was extremely questionable. It was realized that its dispersion would be excessive, and that with the powders with which the service was then familiar it would be exceedingly difficult to secure a muzzle velocity sufficiently uniform to do effective work.

DETAILS OF THE BOMBARDMENT

When the bombardment was over an examination of the periods over which it had extended indicated that it had been divided into three distinct series. The first extended from March 23 to May 1; the second from May 27 to June 11, and the third from July 15 to August 9. It seems certain that this division into series was a part of the plan of the large offensives being waged during that time. Table 1 on page 99 gives the bombardment by days during this entire period and shows the number of projectiles falling within and without the walls of Paris each day, and the number of people killed and wounded. During the first few days of the bombardment the first projectiles arrived between seven and eight o'clock in the morning and continued to fall at intervals of 15 min. through a portion of the day. On later days the bombardment would begin at 12.40 noon.

Much has been said with reference to the effect of this bombardment on the people of the city of Paris. The writer's first direct acquaintance with the bombardment was during the third and fifth days. With considerable surprise it was observed that already the people were taking it quite philosophically; in fact, it could not be seen that they were paying much attention to it at all. At intervals of about fifteen minutes muffled explosions would be heard in different parts of the city, seldom two consecutive explosions in the same vicinity. Many people would stop for an instant and attempt to decide from what direction the sound had come, after which they would go on their way apparently unconcerned. It was, of course, still sufficiently novel to be of considerable interest, and people were talking about it everywhere. It is quite probable that the regularity with which the projectiles were arriving got on the nerves of some people, and that the bombardment was responsible for the departure of some of those who were crowding the trains west and south from Paris. It seems more certain, however, that by the first of June the close proximity of the Germans to the city of Paris, together with the anxiety caused by another drive impending, added to the effect of the heavy bombardments from airplanes on every clear night, had far more effect than the gun. The visible destruction of property was so slight as to give little evidence to any one traveling about the city that the explosions they were hearing from time to time amounted to anything. The newspapers were very careful to avoid any discussion or even a lengthy reference to the bombardment from day to day, and neither gave the locations of the places where the projectiles had fallen nor the number of killed or wounded.

The Germans must certainly have known that their gun was not a profitable investment for the destruction of property, hence they must have continued the bombardment purely for its destructive effect on the morale of the Parisians and its beneficial effect on the morale of the Germans. This is likely the purpose which prompted the construction of the guns. In his book, My Thoughts and Actions, General Ludendorff says: "During the battle we had commenced bombarding Paris from near Laon with a gun having a range of 75 miles. This gun was a marvelous product of technical skill and science; a masterpiece of the firm of Krupp and its director, Rausenberger. The bombardment made a great impression on Paris, and on all France. Part of the population left the capital and so increased the alarm caused by our successes." He is right, the bombardment did make a great impression; it made every one more angry, and alarmed very few. It is certain now that they could ill afford to use their manufacturing facilities for the making of such guns as these at a time when they were so desperately in need of heavy field guns to assist their armies in their big drives.

Long-range or super guns received consideration from the Allies for a very short period. There was a tendency at the time to favor construction of a great number of them, but a saner view soon prevailed and actual steps were taken for the construction of only a very few. Both the British and the French Governments began the construction of a limited number, some of which have now been finished. They built them, however, with a clear understanding that they could hope for but little more from them than the Germans were getting from their own. American ordnance officers feel that it would not profit us to construct more than two or three such guns at the very most, and probably none at all.

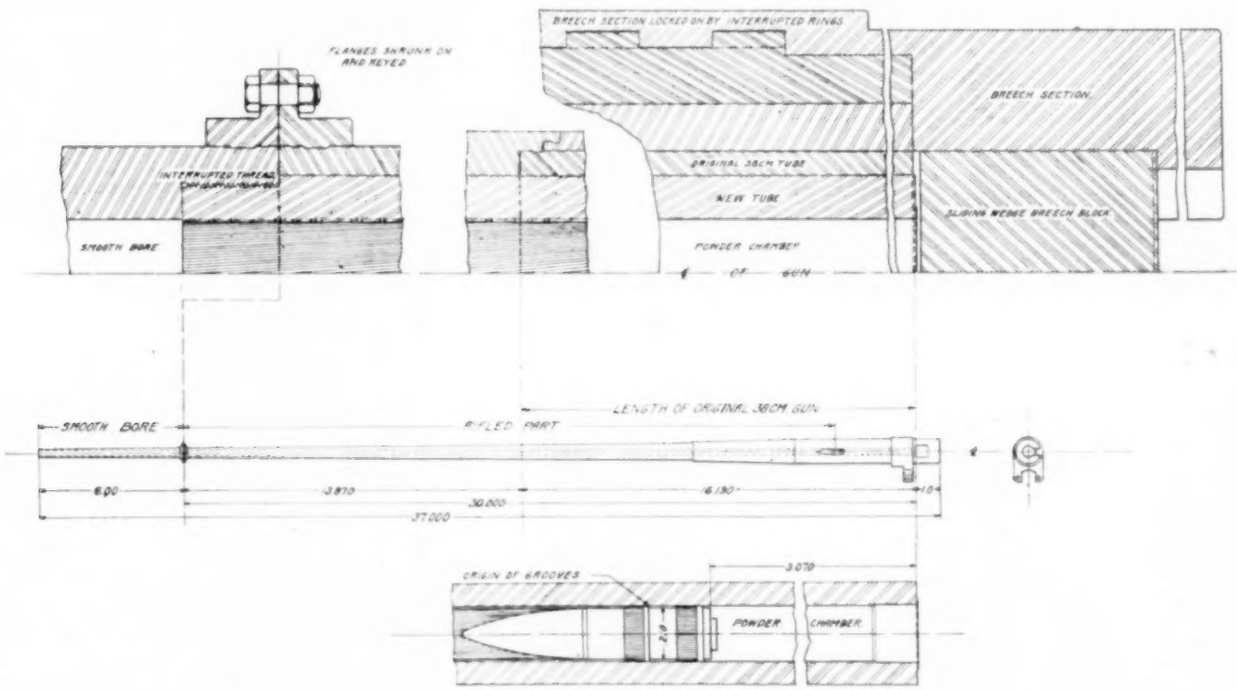


FIG. 4 DETAILS OF DESIGN OF THE GERMAN SUPER GUN (DIMENSIONS IN METERS)

Within a very few days from the beginning of the bombardment it was possible, through careful examination of the direction of the passage of the projectiles through various buildings, to determine quite accurately the direction of their arrival and the probable place from which they were coming. This place was in the Forest of Gobain, southwest of Laon. Very soon thereafter the French Air Service was able to locate in this same forest three positions from any one of which, or possibly from all of which, the guns were being operated. Only one of these was sufficiently close to the German and the Allied lines to permit of any possibility of operating against it with the heavy guns then in service. The gun selected was a 34-cm., 45-caliber French gun on a railway mount. This mount was run up to a point very close to the lines and behind a hill of such size as to effectively conceal it from German line observers. It was well camouflaged by nets against the air observer and against German sound-ranging apparatus by placing two smaller guns at the right and left and several hundred yards behind it. These smaller guns were fired at intervals of one and two seconds before the larger gun, and evidently had the effect of so disturbing the German sound-ranging apparatus as to make it impossible to locate the heavy gun. After a half-day's firing from the 34-cm. gun, air photo-

graphs indicated that the emplacement had been destroyed. The airmen undertook to demolish the other two emplacements, and their photographs indicated that they had inflicted considerable damage. Apparently they did not secure any direct hits, for the gun or guns continued to fire without any long intervals between shots.

After the advance of the Allies it was impossible to determine from examination of the emplacement which had been nearest the Allied lines whether a gun had actually been on this position or not. A German artillery officer who worked with the Americans for some time in the forward area after the armistice, and who

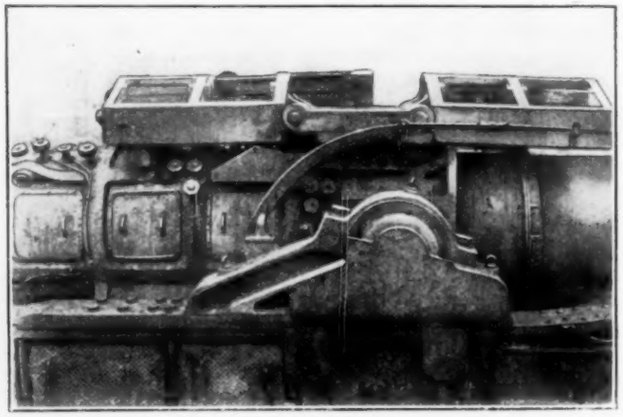


FIG. 5 CRADLE, COUNTERWEIGHTS AND ELEVATION ARC OF GERMAN SUPER GUN

spoke with such certain knowledge of the long-range gun as to indicate that he knew the details of design and had seen it, insisted that the position that had been destroyed by the Allies had not had any gun on it.

Mention has already been made of the destruction of property by these long-range projectiles. Except in a few places where the damage was so exposed as to attract attention, no matter how slight it might be, there was little evidence that the bombardment had any effect. On March 29, the day on which the second gun began to fire, and fired only four projectiles, the one projectile which landed within the city of Paris struck and knocked out the keystone in one of the arches in the roof of the church of St. Gervais near the Hotel de Ville. The falling of the keystone caused a large part of the arch and the roof to collapse, and most unfortunately the church was quite full of people at the time. Examination of Table 1 will show that this day holds the record for casualties. On one other occasion a projectile burst in the lobby of a hotel, killing a number of people but doing comparatively little in the way of material damage. Ordinarily an explosion would make only a comparatively small hole in the ground.

Even during the active periods of the three series noted above there were many days on which the gun did not fire. It is quite certain that between the 25th and 29th of March the first gun was being removed and a new one placed on the carriage. By the end of the 25th of March 49 projectiles had arrived, and the probable life of the guns is not more than 50 rounds. It is likely that the guns were changed again between the 7th and 11th of April and between the 21st and 24th of April.

After the armistice it was learned that the Germans had constructed a total of seven guns. These guns were first constructed to a diameter of 21 cm., and after being worn out as 21-cm. guns were rebored to 24 cm. All of the projectiles of the first two series were 21 cm. in diameter, but during the last days of the third series the projectiles were 24 cm. in diameter, indicating that the entire seven guns had been worn out, and that probably the gun that had commenced firing on Paris on March 23 as a 21-cm. gun had been rebored and fired again as a 24-cm. gun. It was learned also that the Germans were reboring the remainder of the seven guns and were constructing additional guns at Essen. Representatives of the Ordnance Department found in the Skoda Works at Pilsen three more guns, which the engineer at these works said were under construction as long-range guns at the time of the armistice. In July, 1918, the Intelligence Service transmitted information to the effect that one gun had been destroyed by a premature explosion. No confirmation of this report has ever been found, and it cannot be considered a certainty.

The third series began on July 15 with ten projectiles, followed by four projectiles on the 16th. The bombardment then ceased for three weeks, beginning again on August 5 and continuing daily until the 9th. On this day twelve projectiles arrived, only two of which fell within the walls of Paris. The famous bombardment was finished. A comparison of the distribution of the bursts on this last day (Fig. 2) with the locations on the first day (Fig. 1) is very interesting. On the first day a considerable number of the projectiles fell within a very small area in the northeast of Paris. On this last day it will be observed that they are scattered over the western section of Paris, and no two are very close together. The last projectiles of the entire bombardment fell between one and two o'clock on August 9. Already the Allies in their successful drive north of the Marne and between Soissons and Rheims were driving the Germans back so rapidly and had made such progress as to put the long-range guns in serious danger.

Fig. 3 shows the location of all of the bursts within the walls

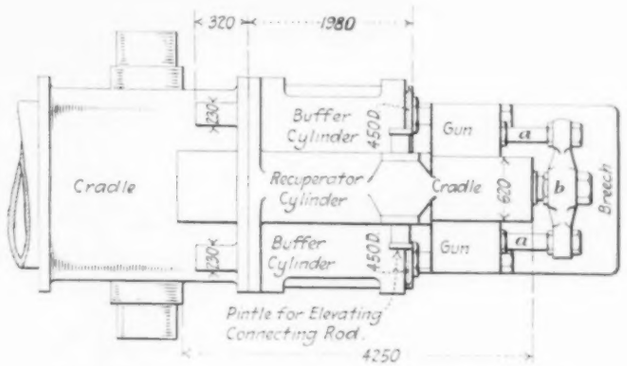


FIG. 6 RECOIL AND RECUPERATOR MECHANISM, BOTTOM PLAN

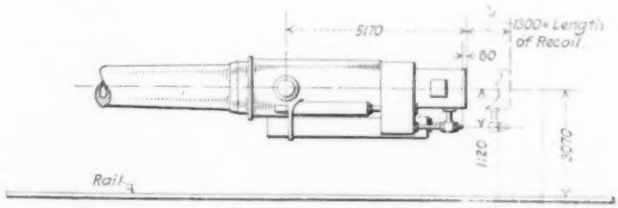


FIG. 7 CRADLE-RECOIL MECHANISM

of the city, a total of 183; 120 more fell outside of the city, making a total of 303 fired from seven 21-cm. guns, and probably one gun rebored to 24 cm. The bombardment continuing actively over forty-four days. Even before the last day of the bombardment American forces operating north of the Marne had captured an emplacement 9 km. (5 miles) north of Chateau-Thierry. This emplacement will be described in detail later. It was 86 km. (53.4 miles) from Paris, and it is understood that it was a new emplacement from which the Germans had hoped to operate the super guns more effectively.

DESIGN OF THE GUN, CARRIAGE AND EMPLACEMENT

It has been mentioned before that the Germans used seven guns of a caliber of 21 cm. or 8.15 in., that they had rebored at least one of them to 24 cm. or 9.3 in., and that at the time of the armistice three more guns were under construction at the Skoda

Ordnance Works at Pilsen in Austria. During the period of active warfare many reports were received with reference to the design of the gun, but never any information with reference to the carriage. The various reports on the gun agreed quite closely in the essential details.

In May 1919 a commission of ordnance officers was sent to the Skoda Works in Austria for the purpose of investigating their methods of constructing large and small ordnance. While there they secured additional data from the chief engineer of the plant with reference to the design of the gun, and saw the three guns which had been in process of construction on November 11, 1918. This engineer stated that when the first German gun began to fire on Paris, it was as much a surprise to the Austrians as it was to the Allies. Shortly thereafter he went to France to examine the gun and observed it in action. It was not until a few months before the armistice that the three guns were sent to Pilsen for conversion into long-range guns. Evidently the Germans had considered the bombardment a success, or sufficiently so to warrant the use of manufacturing facilities for the construction of a greater number of guns than they were able to handle at the Krupp Works at Essen.

The details of the design of the carriage for the gun were not learned until April 1919, although it had been quite certain since August 1918 that the emplacement found southwest of Fere-en-Tardenois was intended for the carriage of the long-range gun. Until July 1, 1919, no direct information had been received from the Germans with reference to the design of any part of the entire

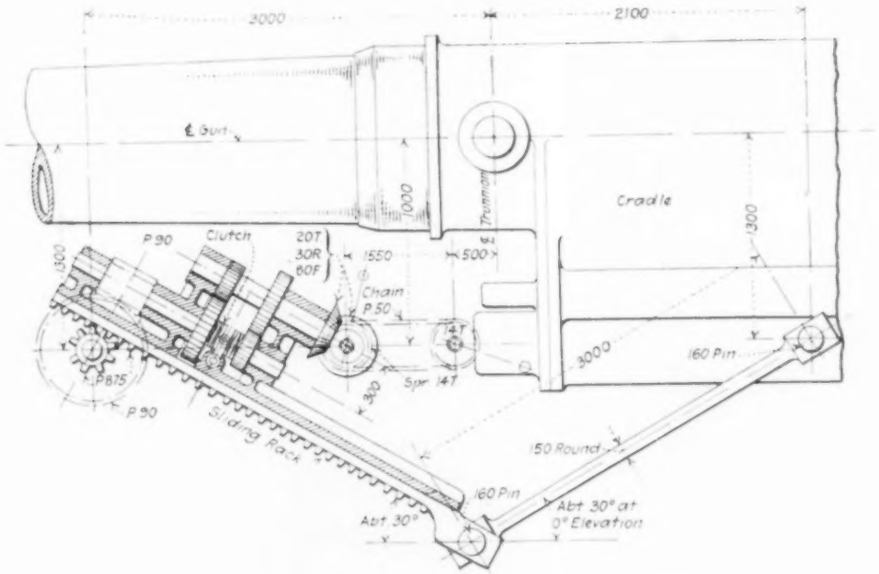


FIG. 8 SIDE ELEVATION OF ELEVATING MECHANISM

mechanism except the gun on which, as mentioned before, information had been received at various times before the armistice; the guns themselves were examined at the Skoda Works at Pilsen. Just why the Germans refused to talk about this gun is not known. In December 1918 and January and February 1919 a German engineer who was working with the American forces in the region northeast of Verdun helping identify long-delay fuses and assisting on other technical matters said that he was acquainted with the design of the gun and had seen it in operation. Very curiously, however, he refused to give any information with reference to the details of the design and was quite positive in his assertions that the Allies would never see any of the guns, and certainly not any of the carriages. This was difficult to understand in view of his perfect willingness to talk about the details of design of any other piece of ordnance that he was at any time asked about, and it was more curious in view of the fact that there is really nothing wonderful about the design of the long-range gun, its carriage or its emplacement.

THE GUN

All of the long-range guns were constructed from worn-out 38-cm. (15-in.) 45-caliber (17.1 m. or 56 ft. in length) naval guns. The converted gun was in two parts, the main section 30 m. or 98.5 ft. in length, and the forward section 6 m. or 19.7 ft. in length. The 38-cm. gun was bored out and a very heavy tube with an inside diameter of 21 cm. was inserted, Fig. 4; 12.9 m. or 40.23 ft. projected beyond the end of the original gun, and over this projecting portion another hoop was shrunk and locked to the forward hoop of the old gun. This 21-cm. tube was rifled at a uni-

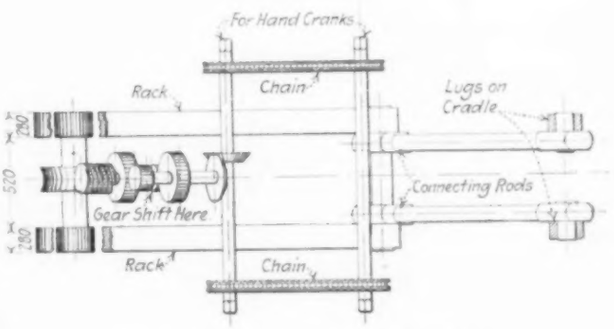


FIG. 9 PLAN OF ELEVATING MECHANISM

form twist throughout its length. The other section, 6 m. in length, was attached by means of an interrupted thread and heavy outside collars or flanges. This section was unrifled and was of an inside diameter equal to 21 cm. plus twice the depth of the grooves in the rifled section. It was assembled to the gun in the field and not removed until the gun had been worn out. The total weight of the original 38-cm. gun was 152,550 lb., and the weight of the reconstructed gun approximately 318,000 lb. The 21-cm. liner was of such thickness that on being worn out at this caliber it could be rebored first to 24 cm. (9.3 in.) and later to 26 cm. (9.93 in.). Its probable life at any one caliber was not more than 50 rounds, and the maximum powder pressure did not exceed 3000 atmospheres or 44,000 lb. per sq. in. The design of the breech mechanism of the original 38-cm. gun did not require modification.

The long-range guns constructed by the British and French governments do not follow the German design to the extent of having a smooth-bore section on the front. The purpose of this feature was for some time in doubt and is worthy of some discussion.

The gun just described is approximately three meters longer than either the British or French long-range guns, both of which are rifled throughout their length. Two reasons might be given for the extra section.

Possibly additional linear velocity was imparted to the projectile as it traveled through the 6-m. smooth-bore section. It seems improbable, however, that this could be its primary purpose, inasmuch as the muzzle velocity was such a variable quantity. It is more probable that its purpose was to align the axis of the projectile more perfectly with the axis of the bore of the gun and reduce to a minimum the angular velocity of yaw as the projectile left the muzzle. When it is understood that this projectile was to mount to a height of about 24 miles and travel a horizontal distance of 76 miles, it can easily be appreciated that any tendency that the projectile might have to throw its axis out of alignment

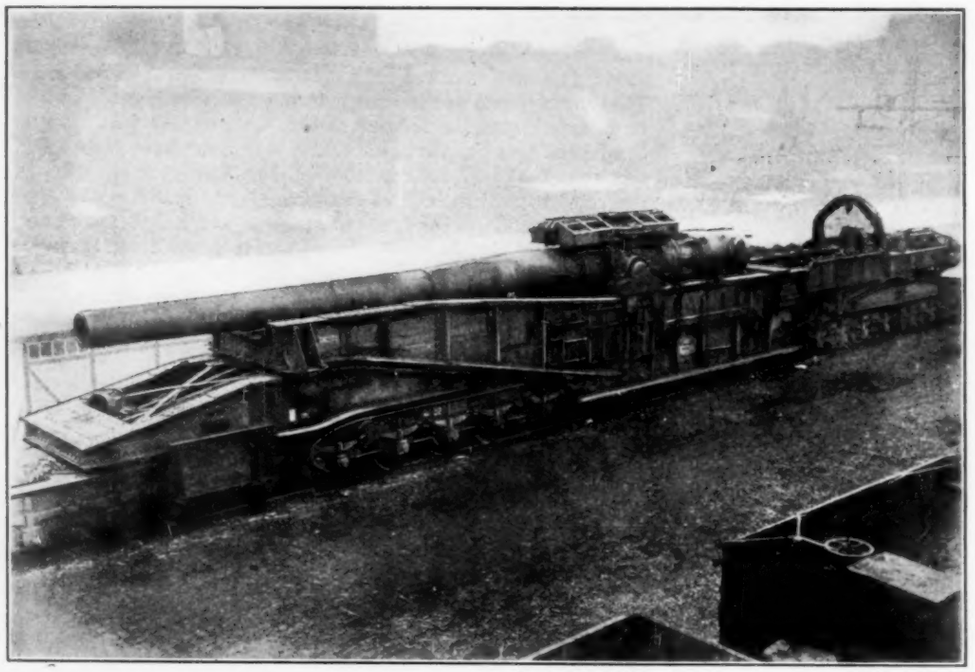


FIG. 10 THE GUN CARRIAGE. (THE GUN SHOWN IS THE 38-CM. 45-CALIBER GUN FROM WHICH THE LONG-RANGE GUNS WERE MADE)

with its theoretical path would have disastrous results. Through the impracticability of making projectiles fit perfectly in a gun they have a tendency to hammer the walls as they travel down the bore. This hammering action of the projectile is the result of the operation of two forces, the one tending to increase its linear velocity and the other to increase its rotational velocity. The latter force is acting only while it is traveling through the rifled section. It is invariably true that just as the projectile is leaving the ordinary gun it is on one of its up, down or crosswise hammer strokes, and that the axis has a tendency to yaw or deviate from its theoretical path at a certain angular velocity. Cardboard screens placed in front of guns in proof firing invariably show elongated holes, and not infrequently very decidedly so, even at no greater distances than 100 ft. from the muzzle. This tendency to yaw has a detrimental effect on the accuracy of even our comparatively short-range guns, but no effective means have yet been devised to neutralize it. With the extreme-range gun it is so much more serious that it seems quite likely that the Germans adopted this method of neutralizing it, thereby reducing the dispersion both in range and in direction. It is not improbable that the German gun was first constructed without the smooth-bore section, and that its shooting was found to be so erratic as to require the addition of this feature.

This gun was operated at a muzzle velocity of from 1500 m. (4760 ft.) to 1600 m. (5090 ft.) per sec. and at an elevation of 55 deg. This 55 deg. is worthy of comment, inasmuch as it has ordinarily been supposed that nothing could be gained in range by elevating a gun above 45 deg. It is known, of course, that if a projectile is fired in a vacuum its maximum range is attained when it starts at an elevation of 45 deg. When fired in the air, however, the initial angle which permits it to attain its maximum range depends both on the caliber and weight of the projectile and the velocity at which it leaves the gun. With reasonably large and well-designed projectiles, it may be said that for each muzzle velocity (*a*) there is a density of air (*b*) into which the projectile should enter at an approximate elevation of 45 deg. For this projectile and the muzzle velocity of 1500 m. per sec. the initial elevation of the projectile is 55 deg. It is very doubtful whether any additional range can be secured with any projectile at any muzzle velocity at an elevation above 55 deg.

Attention was called in the discussion of the first day's bombardment to the tremendous dispersion in range. Some of the projectiles fell just within the wall at the northeast side of Paris, and some within the walls at the southwest side. This is accounted for by the fact just mentioned that the muzzle velocity of the projectile varied as much as 100 m. per sec. It was impossible with the powder that the Germans were using to secure a muzzle velocity with a variation of less than 100 m. per sec.

THE GUN CARRIAGE

Cradle. The cradle, Fig. 5, is a cylinder of simple design having ribs at long intervals and of a depth of only about 3 cm. The walls of the cylinder have a minimum thickness of 10 cm. and a maximum thickness of 13 cm. over the ribs. The diameter of the main trunnion is 46 cm. and the length 33.5 cm. A collapsible counterweight is attached to the top of the cradle. In firing, the two sections of this counterweight are raised and locked together for the purpose of raising the center of gravity to such an extent that the gun may be elevated and depressed more easily. This cradle is of a naval design, the front section being so shaped as to close the opening in a turret. It is not improbable that the cradle as well as most of the 38-cm. guns were removed from German ships or coast fortifications.

Recoil Mechanism. The recoil mechanism is composed of two hydraulic recoil cylinders and one spring-pneumatic recuperator cylinder, all attached to the bottom of the cradle, Figs. 6 and 7.

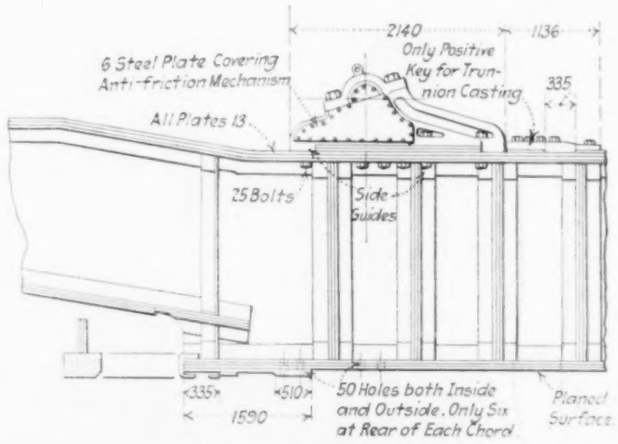


FIG. 11 GIRDER DETAILS

Each of the recoil cylinders is a separate cylinder carried in brackets cast on the cradle, and each is provided with a buffer approximately 32 cm. long. The plugs through which the cylinders are filled are on the ends of the buffers. The approximate length of recoil is 1.3 m. (50.5 in.). This distance is, of course, approximate and was arrived at after careful examination of the cradle. A report examined in the office of the Chief of Artillery of the Belgian Army at Brussels gives the length of recoil as 1.15 m. Inquiry disclosed the fact that this length of recoil was also approximate.

Two rods *a*, *a*, screwed to the recoil lug of the gun, Fig. 6, and extending to the rear, carry a heavy crosshead *b* to which the

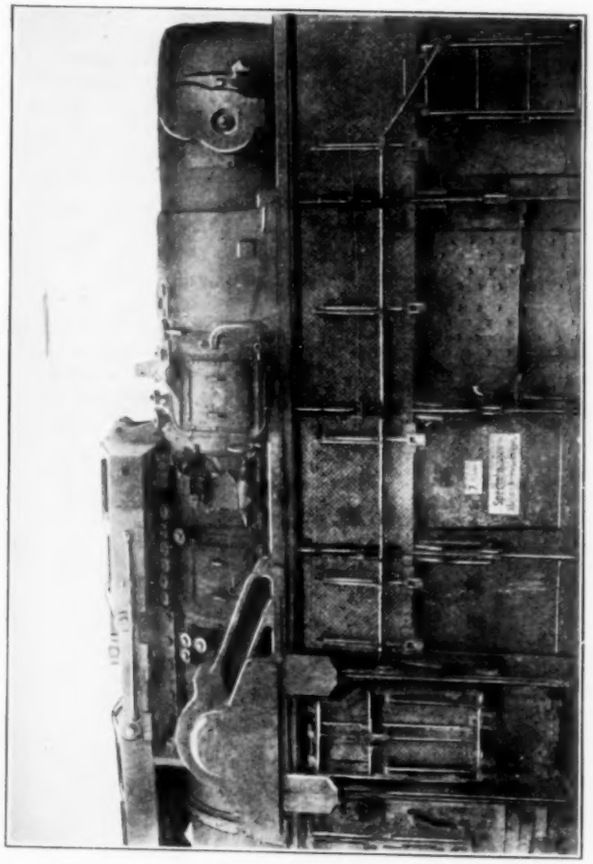


FIG. 13 SIGHT, RECUPERATOR PUMP AND BREECH MECHANISM

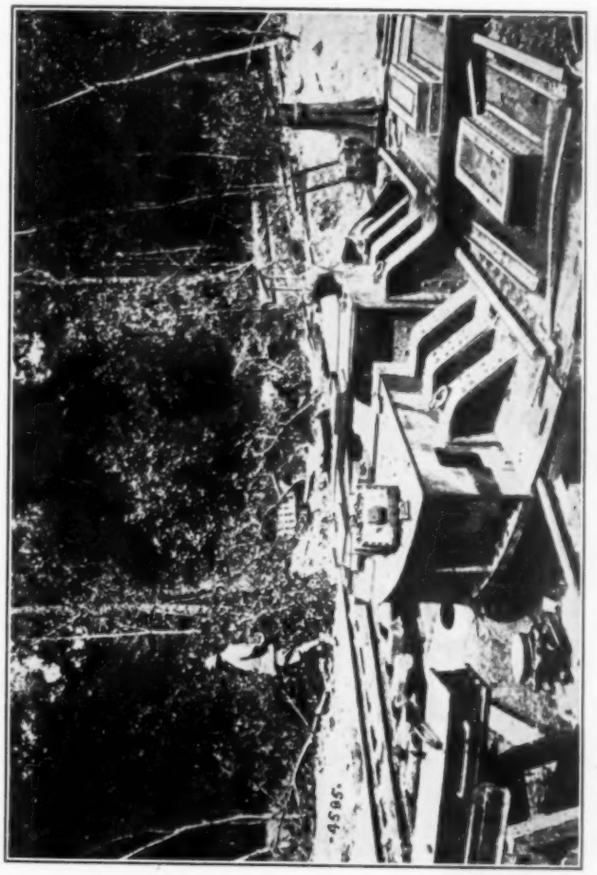


FIG. 15 ANOTHER VIEW OF EMPLACEMENT SHOWN IN FIG. 14

FIG. 12 DETAILS OF GUN CARRIAGE

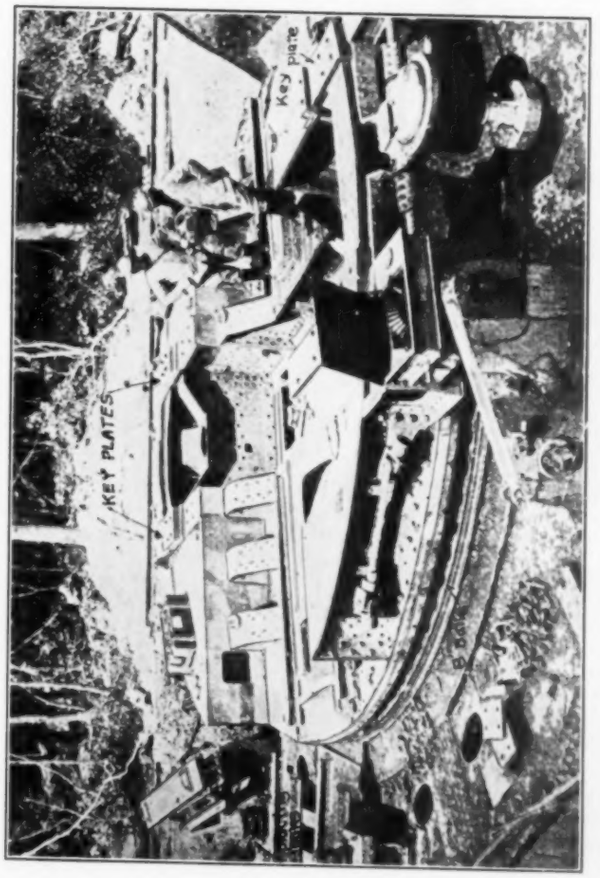


FIG. 14 EMPLACEMENT (BOIS DU CHATELET)

piston of the recuperator cylinder is attached. The recuperator cylinder is likewise a separate cylinder carried in brackets cast on the cradle. At the rear on both sides it is planed to serve as a guide for the recoil lug to prevent rotation of the gun.

Elevating Mechanism. The elevating mechanism of this mount is extremely heavy and unique in design. The cradle was evidently originally provided with the screw type of elevating mechanism, the screw being hinged to the cradle at the rear end.

The specification that the gun be provided with an elevation of 55 deg. necessarily led to the discarding of the screw mechanism. The straight racks shown on Fig. 8 slide in ways which are parallel to the inclined lower face of the forward end of the side girders. It was necessary to put them in this position to secure sufficient movement to attain to 55 deg. At the lower end they are connected with each other by a heavy shaft to which are attached the two connecting rods running up to the bottom of the cradle (Fig. 9). Provision is made for two handles on each side of the car, each for two men, Fig. 9, and a two-speed transmission is provided, permitting the mechanism to be operated at low or high speed. The ratio of the low-speed gear is $4\frac{1}{8}$ turns of the handle for each degree of movement of the gun. It was not possible to determine the ratio of the high-speed gear, since the two men making the examination could not operate it. It seems probable, however, that eight men could operate the mechanism at high speed without undue difficulty.

Traversing Mechanism. See later paragraphs dealing with the anchorage.

Railway Car Body. The railway car body shown in Figs. 10, 11, 12 and 13 is made up of two single-web side girders connected at the front and rear by heavy structural-steel transoms. They are further reinforced in the front by the heavy cast-steel housing for the elevating gear. The trunnion seats are of cast steel and are simply bolted to the top chord with single key plates at their rear. This single key plate has the positive backing of one top cover plate. The face of the horizontal section of the lower chord of the side girders is planed and is provided with key plates at each end, Fig. 11. Eight 2-in. holes are provided in each lower chord at the front end and six at the rear for bolting the mount to the emplacement.

THE ANCHORAGE

When the German Army had retired from the salient between Soissons and Rheims in August 1918, the emplacement shown in Figs. 14 and 15 was found in the Bois du Chatelet, 9 km. directly north of Chateau-Thierry. This emplacement was in process of

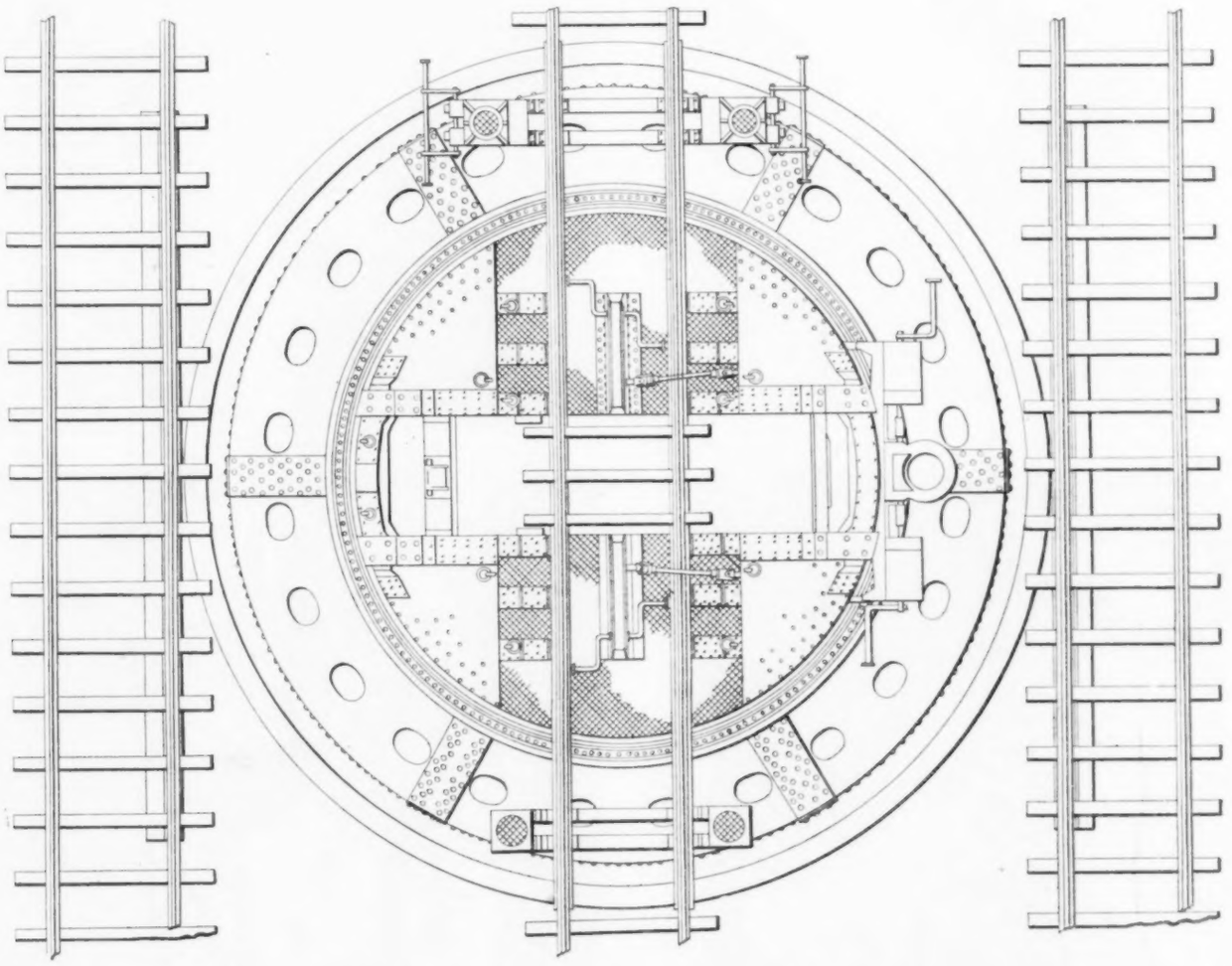


FIG. 16 PLAN OF EMPLACEMENT SHOWN IN FIGS. 14 AND 15

installation, and had not been completely erected. The Germans attempted to destroy it, but succeeded only in ripping loose a few plates. At the time the emplacement was captured, no description of any kind was available of the carriage for which it was intended. The writer's failure to find any emplacement in Belgium from which the mount examined there could be operated led to further examination of the emplacement in France, and it was found that they fitted perfectly.

The emplacement is in two main sections, one a base and the other a rotating section. The rotating section, which is shown in Figs. 16 and 17, is about 28 ft. 6 in. in diameter and is supported on 112 8-in. steel balls. The base of this section is about 35 ft. in

diameter and 6 ft. in depth. In Fig. 14 there can be seen at right angles to the direction of the track of the rotating section two girders, on the ends of which are key plates or pads. The plate which is labeled has six holes in it, and the plate on the opposite end of the girder has eight.

The mount is run on to the emplacement with the rotating section in the position shown in Fig. 14. It is then raised by the four jacks, which can be seen at the left of Fig. 14, and are shown in their exact positions in Fig. 16. When the mount is raised the trucks are removed and the rotating section of the emplacement turned through 90 deg. On lowering the mount on to the emplacement, the key plates on the bottom chords of the carriage are fitted to the corresponding key plates on the emplacement. The emplacement is shown in process of installation, with the gantry crane still in place, Fig. 19.

The carriage on which the gun is so mounted as to be capable of movement in a vertical plane only is traversed by rotating the top section of the emplacement. A complete circular traversing rack made up of angles and steel pins is bolted to the structural base (page 89). A pinion carried on a vertical shaft on the side of the rotating section which corresponds to the rear of the carriage engages with this rack, and the mechanism is driven by two two-man handles on a horizontal shaft carrying a worm engaging with a worm wheel on the top of the vertical shaft, as shown at the right of the top view, Fig. 16. This shaft may likewise be driven by means of the four handles mounted on the two cases in the center of the rotating section and connected with the worm wheel and shaft through two shafts carrying two universal joints each. Apparently the mount was generally traversed by means of these latter handles, if one may judge of the scheme of operation shown in the illustration on page 89.

Camouflage. In the case of the emplacement found in the Bois du Chatelet, sockets were placed in the center of the approach track at intervals of about 30 ft., into which trees with trunks up to about 6 in. in diameter could be placed for the purpose of concealing these tracks. In the illustration of the gun in action, page 89, it will be observed that netting has been stretched over the mount from the trees on either side, and in Fig. 19 it can be seen that the gantry crane as well as the emplacement, while in the process of installation, were covered with tree branches.

Trucks. All of the trucks as well as the span bolsters are constructed entirely of structural steel as shown in Fig. 20. The front trucks contain five axles each, and the rear trucks four axles each. The journals are approximately 14 cm. in diameter by 22 cm. in length. The wheels are 95 cm. in diameter. On the front trucks three wheels are provided with two brakeshoes each; on the rear trucks the end wheels are provided with two shoes each and the inner wheels with one shoe each. The braking is done by hand only. The axles are equalized in pairs only. The center axles of the front trucks have no connection with the others. In Fig. 10 a portion of a circular rail can be seen on the top of the front truck on which the pads attached to the span bolster on each side bear.

Ammunition Supply System

The provisions made for supplying ammunition are shown in Figs. 21, 23, and 25. These same provisions were used for the operation of the 38 cm. 45-caliber naval guns from which the long-range guns were made. The extension to the ear body shown in Fig. 21 was used for the operation of the 38-cm. gun under certain conditions. This was not required and was removed when the long-range gun was operated on the carriage. In Fig. 25 a removable plate can be seen between the shot-truck rails. Above this removable plate is a light bridge, in the center of which is seen a ball on the end of the cable used in hoisting projectiles through the hole in the floor. This cable runs over a series of pulleys to a small drum in the box on the top of the left-side girder. The ammunition was supplied from the storehouse over the narrow-gage track shown in Fig. 23, the circular portion of the track being under the opening in the center of the floor of the mount. The gear in the box on the side girder is of the double-speed variety, the high speed being provided probably for rapid operating in the hoisting of powder.

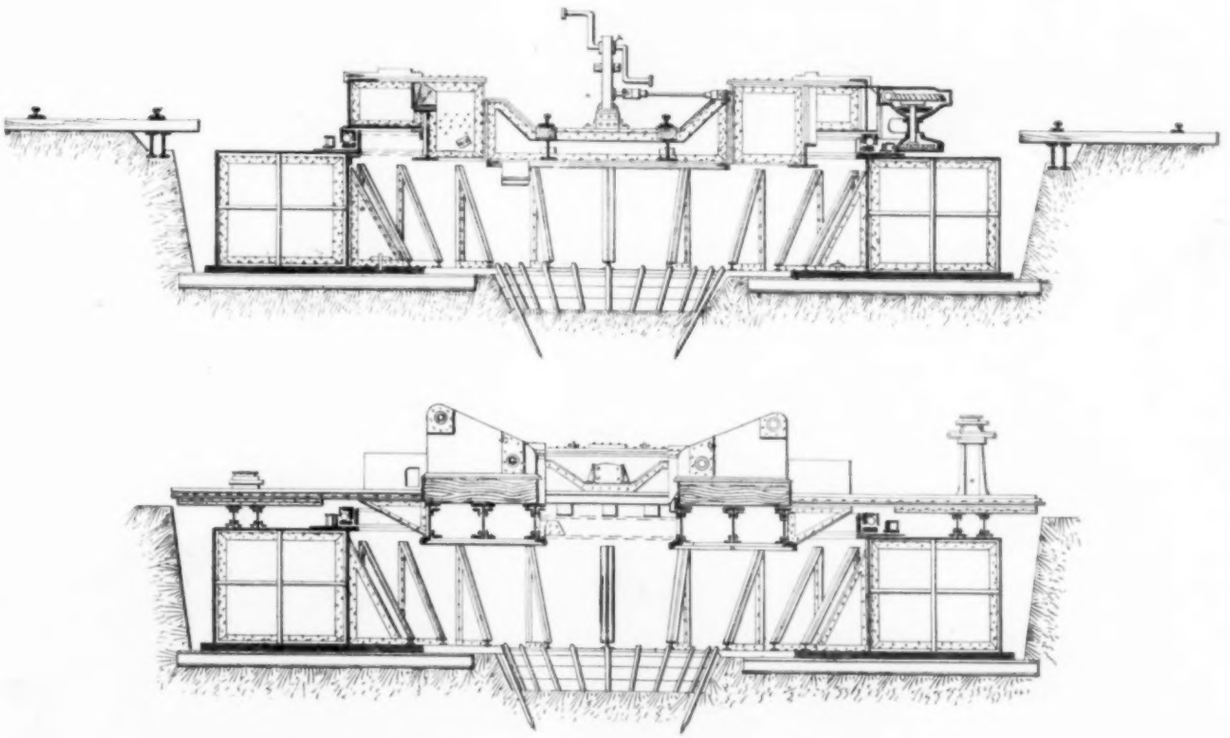


Fig. 17 Elevation of Emplacement Shown in Figs. 14 and 15

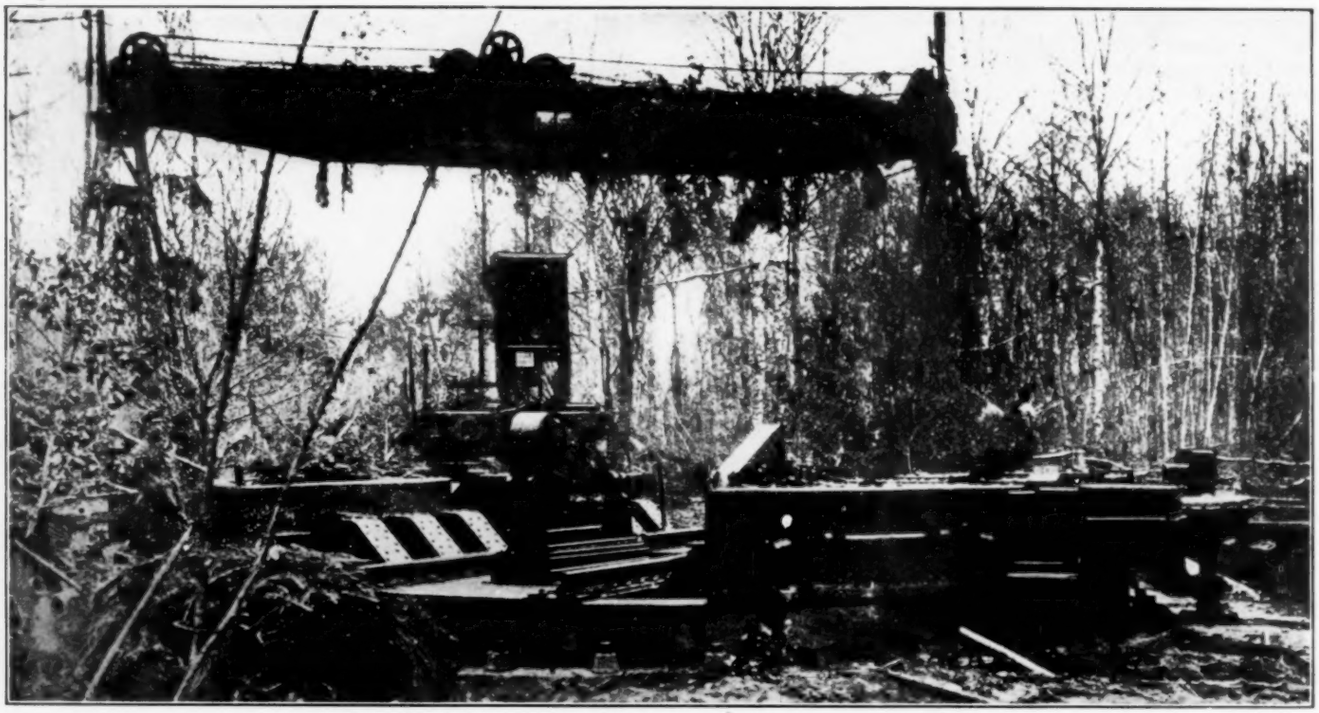


FIG. 19 EMPLACEMENT IN PROCESS OF INSTALLATION

AMMUNITION

The projectile used with this gun is shown in Fig. 24. Its weight is 120 kg., or 264 lb. The length of the main portion of the projectile is 490 mm., or approximately 19 in. To this was attached a false ogive or cap, the exact length of which is not known; it was probably as long, if not slightly longer, than the main portion of the projectile. The radius of the curve of this ogive was about 7 calibers or 58 in. The design of the interior as well as the exterior of this projectile is unique in many respects. It will be noted that the charge was separated into two parts by a diaphragm which has a number of holes in it. Two fuses are used, the one in the diaphragm and the other in the base. All of these projectiles were most carefully machined to elaborate specifications in order that the weight and dimensions might be practically exact and the center of gravity perfectly located; even after they were thus machined they were sorted out into lots according to their characteristics by weight, dimensions and location of the center of gravity, and the various lots of projectiles marked with center-punch marks. The necessary corrections in elevation and deflection were calculated for the projectiles of these various lots. The projectiles which fell in Paris were successively marked with three center-punch marks in a triangle or four center-punch marks in a square, etc.—projectiles of the same marking arrived consecutively.

The outside of the projectile was provided with two copper bands which served as gas checks, and in front of each of these copper bands the projectile was enlarged and rifled for a length of 70 mm. or 2.7 in. The shear from the extreme acceleration necessary to produce the required muzzle velocity was such that the ordinary copper bands could not be made to serve as rotating bands. The shearing strength of the copper is not sufficient to stand the strain that would have been put on the bands with so great an acceleration. The friction between the lands of the gun and the projectile was so great as to wear the gun appreciably on each round fired. This was evident from examination of the copper bands of successive projectiles. As a result of the necessity for providing rifled projectiles, it was necessary in placing

FIG. 20 TRUCK DESIGN

the projectile in the bore of the gun to fit the forward rifled section of the projectile into the beginning of the rifling of the gun, Fig. 4. The exact details of the design of the portion of the tube between the beginning of the rifling and the powder chamber are not known. It seems quite probable, however, that there is a smooth section of about 12 in. into which the portion of the projectile back of the first copper band fits, bringing the base of the projectile to the end of the powder chamber. The fact that the forward rifled section of the projectile was already fitted into the grooves of the gun made it certain that the rifled section at the rear would likewise fit as the projectile began to move up the gun.

TABLE 1 BOMBARDMENT OF PARIS BY THE GERMAN LONG-RANGE GUN

(March 23 to August 9, 1918.)

Dates		Number of Projectiles		Killed	Wounded
		Within the Walls	Outside the Walls		
March	23	18	3	15	36
	24	13	9	11	34
	25	4	2	1	3
	29	1[1]	3	88[2]	68
	30	18	3	10	60
	31	3	..	1	1
April	1	3	1	8	8
	2	3	1	..	3
	3	1	..	..	..
	6	2	4	..	3
	7	..	1	..	..
	11	5	1	9	21
	12	5	2	2	14
	13[3]	6	2	..	..
	14	3	1	..	..
	15[3]	3	2	..	..
	16	2	1	17	114
	19	1	2	..	..
	21	2	..	..	..
	24	..	1	..	..
	25	6	4	1	..
	26[3]	1	..	..	..
	30	..	3	..	..
May	1	..	1	..	5
	27[3]	7	7	4	20
	28	6	4	1	2
	29	5	5	1	7
	30	4	5	13	5
	31	1	3	..	..
June	1	..	4	..	..
	3	..	6	2	8
	4	4	..	4	16
	7	3	1	1	4
	8	1	2	3	..
	9	1	3	1	9
	10	2	2	3	13
	11	..	1	..	..
July	15	9	1	6	9
	16	4	..	3	8
August	5	13	4	32	61
	6	12	7	8	39
	7	8	4	7	43
	8	1	4	1	..
	9	2	10	3	6
Totals		183	120	256	620

[1] Shell struck an arch in the roof of the Church of Saint Gervais. [2] Night and day. [3] Night.

It has been noted before that this projectile departed at a muzzle velocity of from 1500 to 1600 m. per sec. The velocity remaining on its arrival in Paris was approximately 700 m. per sec. and the time of flight about three minutes.

The analyses made of the various parts of the shell are as given in Table 2.

Not a single one of the 303 projectiles that fell in or about Paris failed to detonate. Evidently the two fuses were responsible for this excellent record. The practice of separating the charges into two parts by a diaphragm is not new. The diaphragm had been used before in heavy French projectiles as a guarantee against the effects of inertia which might either provoke a premature explosion in consequence of the friction of the molecules of the charge against each other or might bring the charge beyond the critical density point, after which it probably would not detonate. At one time a theory was advanced to the effect that the diaphragm separated two liquids which mixed and detonated upon the fall of the projectile. There seems no good reason to believe that this could have been so.

Previous Designs and Limits in Design

It has been mentioned already that investigation disclosed shortly after the beginning of the bombardment that an almost identical design had been proposed to the French government not many years before. Further search of French and English records has brought to light the fact that the rifled projectile is quite old and seems to antedate the copper band considerably. In 1892 Sir Alfred Noble made a 100-caliber 6-in. gun which gave a muzzle velocity of 3700 ft. per sec.; in the same year the French government constructed a 10-cm. 80-caliber gun from which they attained almost the same muzzle velocity. It is not known what range was secured in either case. The forms of most standard projectiles at that time were not such, however, as to make it possible to secure the maximum range from the above-noted velocity.

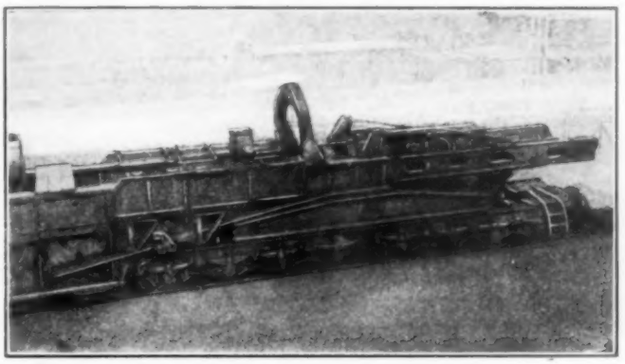


Fig. 21 View Showing Loading Gear, Trucks and Bolster

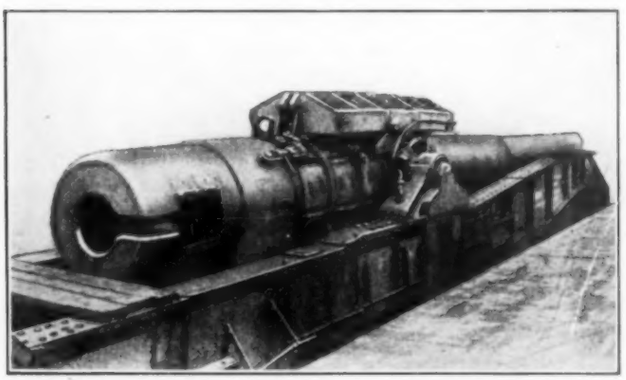


Fig. 22 Breech Mechanism, Recuperator Gage and Traveling Lock

In taking up the design of such guns again the French and English services found that with guns of practicable length and muzzle velocities attainable with guns of such length, and with available powders, the projectile that would permit the greatest range to be realized would be approximately 8 in. in diameter and weigh from 225 to 250 lb. An appreciable change up or down in the diameter or the weight of the projectile would result in a loss of range. The gun designed by one of our allies uses a projectile weighing 240 lb. and a powder charge of 350 lb. One of the

TABLE 2 ANALYSES OF VARIOUS PARTS OF THE SHELL

	Shell[1]	Cap Holder[2]	Cap	Diaphragm[3]	Copper Band	Dunkirk Shells
C	0.43–0.85	0.58–0.73	0.10–0.18	0.60		0.72
Mn	0.27–0.49	0.27–0.36	0.41–0.97	0.09		0.26
Si	0.24–0.31	0.19–0.28	0.03–0.05	0.61		0.23
S	0.04–0.10	0.03–0.07	0.05–0.11	0.04		0.03
P	0.01–0.06	0.03–0.07	0.04–0.067	0.04		0.04
Ni	1.82–2.32	2.10–2.39	0.00–0.11	0.0		2.41
Cr	0.83–1.45	0.95–1.44	0.00–0.2	0.0		1.32
Pb					0.12	
Fe					0.21	
Cu					99.67	

[1] Practically a casting. [2] Cast. [3] Forging.

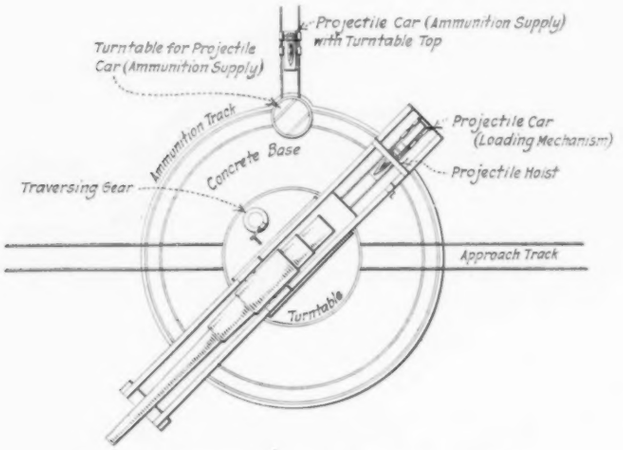


FIG. 23 PLAN OF AMMUNITION SUPPLY SYSTEM

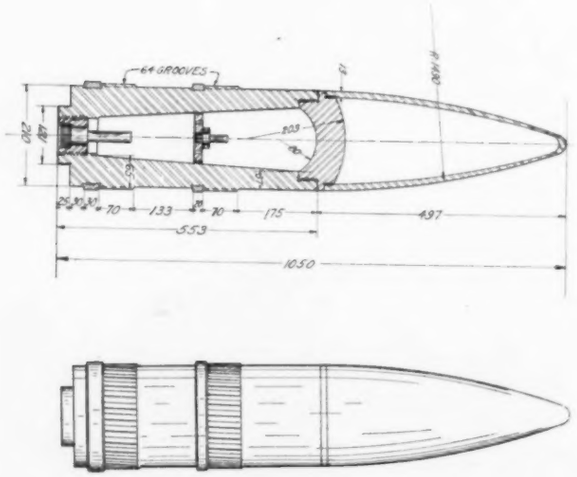


FIG. 24 DETAILS OF DESIGN OF PROJECTILE

pieces of powder examined was about 2½ ft. in length and roughly elliptical in cross-section, the axes being about 1 in. and ½ in., respectively. It is interesting to note in this case that the powder charge has a weight about 50 per cent greater than that of the projectile. If the weight of the charge were increased, calculations indicate that most of the energy of the gas would be absorbed in the work of accelerating the charge rather than in accelerating the projectile, and no greater muzzle velocity would be obtained.

One of the vital requirements made of the powder is that it burn at a rate sufficiently slow to avoid excessive pressures and

FIG. 25 LOADING GEAR

to give a uniform pressure through a large portion of the period of the travel of the projectile in the bore of the gun. The powder made by one of our allies for their long-range gun is in flat strips resembling cardboard. These strips are three-ply, the various sections burning at different rates. The large sticks of powder mentioned above for the gun of the other of our allies is special, and is expected to live up to the characteristics just noted.

A somewhat recent report by the Bureau of Mines is authority for the statement that the metal-mining industry in this country is now passing through one of the most critical stages in its history, and is confronted by new problems upon the solution and adjustment of which depends, in a large measure, its future welfare and prosperity.

The chief factors, according to the Bureau, contributing to the cost of production are the cost of labor and supplies. It is conceded by our leading mine operators, managers, and engineers that any material reduction in the cost of labor or supplies, within possibly the next two or three years, cannot be anticipated, and it is not thought likely that pre-war prices will ever again prevail. This being true, the mine operator must look in some other direction to effect economies that will lower production costs. If this cannot be accomplished it will mean, in many instances, that mines and metallurgical works will have to be closed and abandoned, which will tend to disorganize the entire industry. How to lower production costs and still maintain the present high standard of wage is the problem that is engaging the serious attention of mine operators and managers over the entire country.

As a solution to this problem it is thought that the most promising field of investigation lies in the direction of systematizing and standardizing mining practice so as to effect economies in the use of both labor and materials. Already some of the large mining companies in the West have conducted extensive experiments and research in this direction, and the results obtained have furnished conclusive proof of the value of standardization of mining practice and mining equipment. For example, the Phelps-Dodge Corporation has made in the past year an exhaustive study of the various underground operations in their mines at Bisbee, Ariz., for the purpose of standardizing the mining practice. The results achieved have been most encouraging, and show that costs can be lowered even in the face of advancing prices in labor and material.

The Testing of Farm Tractors

By CHARLES H. BENJAMIN [1], LAFAYETTE, IND.

The future will unquestionably see a great development of the farm tractor, and the testing of these machines will of necessity be an important factor in that development. To assist in this work there has been installed in the Experiment Station at Purdue University a tractor-testing plant, the features of which are described in the present paper. Briefly, the plant consists of three elements, a treadmill, or moving platform, a traction dynamometer, and an absorption dynamometer, and is capable of testing tractors weighing as high as 12,000 lb. on the driving wheels and giving a drawbar pull of 5000 lb. at a speed of not over 5 m.p.h. A detailed description of the plant follows.

THE latest machine to claim the attention of the investigator is the farm tractor. Its development has naturally followed that of the automobile and the motor truck, and the farmer, comparatively isolated as he is, finds the use of individual motive power almost a necessity. But, like all newly invented machines, the farm tractor is imperfect, and will not always do the work expected of it. Field tests throw some light on its good and bad points, but unfortunately they do not always locate the source of poor performance. A laboratory test, on the other hand, if it fairly imitates what we may call standard working conditions, will enable us to compare one machine with another and thus secure information not given by the field test.

To carry on such laboratory tests, apparatus especially designed for the testing of farm tractors has been installed at Purdue University, and it is believed that a description of the installation will be of general interest. The plant itself consists of (1) a treadmill or moving platform, a sort of inverted "caterpillar" supported on driving wheels and idle rollers, and in its turn supporting the driving wheels or lags of the tractor; (2) a traction dynamometer to receive and measure the pull of the tractor; (3) an absorption dynamometer to control and measure the energy transmitted through the treadmill and its supporting wheels.

The plant, which is a permanent equipment for the engineering experiment station, is capable of testing tractors weighing as high as 12,000 lb. on the driving wheels and giving a drawbar pull of about 5000 lb. at a speed not to exceed 5 m. per hr.; these tractors being either single- or double-wheel, front or rear drive, or of the caterpillar type, with maximum tread for the double-wheel tractor of 84 in. and a caterpillar length of 96 in., the face of the drivers not being greater than 26 in.

Description of the Plant

The plant is of the treadmill type having two caterpillar treads of 26 in. width, carried on a structural-steel frame so designed that with little difficulty it can be changed to accommodate the various styles of tractors.

The steelwork consists in part of a main frame made up of three 8-in. I-beams running across the plant resting on permanent supports at each end and on a movable support in the center, all supports being bolted to the foundation.

On the main frame are two rectangular frames which can be moved along the 8-in. I-beams, thus taking care of the different treads of the tractors, or one can be placed in the center to accommodate the single-wheel type. The top of each rectangular frame is made up of four 3-in. I-beams for cross-members, which support the caterpillar tracks. These 3-in. beams can be removed and replaced by a weighing mechanism, so that the weight of the tractor on the driving wheels can be obtained while in operation.

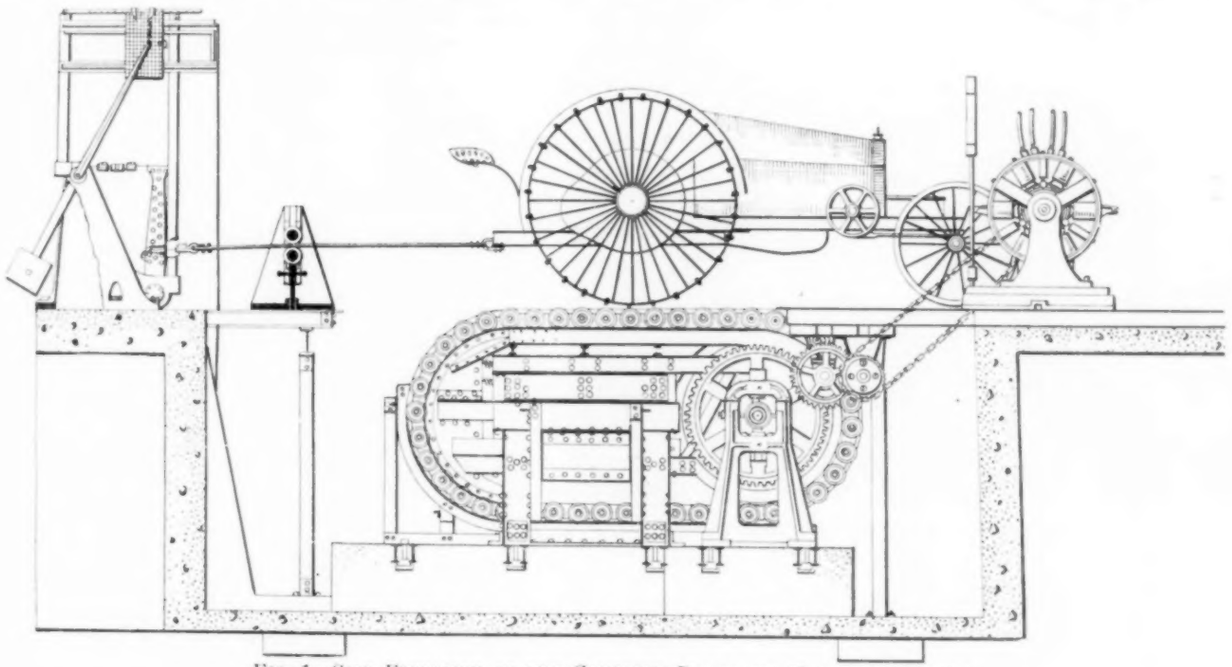


Fig. 1 Side Elevation of the Complete Plant for Testing Tractors

At the rear end of each rectangular frame is a sliding semicircular track which transfers the caterpillar tread from the top to the bottom track, these tracks being forced endways by means of compression springs which maintain the desired tension on the caterpillar tread.

Under the rectangular frame is a separate track bolted to the foundation for the purpose of carrying the weight of the caterpillar tread on the return. Fig. 1 shows a side elevation of the complete plant.

The caterpillar tread consists of ninety-four 7-in. cast-steel links 26 in. wide, each link being carried on four 5-in. wheels equipped with bronze bearings. These wheels provide support

[1] Dean, Purdue University, Lafayette, Ind. Mem.Am.Soc.M.E.

Presented at the Mid-West Sections Meeting, Indianapolis, Ind., October 24 and 25, 1919, of The American Society of Mechanical Engineers.

for the links at all times except as they come around 48-in. pulleys at the front end, when the under sides of the links, which are curved to fit, transmit the pull to the 48-in. pulleys. To the upper sides of the links are bolted hard-maple blocks 26 in. long, 6 in. wide and 4½ in. thick, leaving 1 in. between the blocks. Lugs can be provided on the tractor driver wheels to mesh in the gaps and thus prevent slippage between caterpillar and wheel. Fig. 2 is a general view of the plant.

The 48-in. pulleys which take the pull from the caterpillar tread have glued and riveted to their faces strips of conveyor belting 26 in. wide and ½ in. thick to reduce slippage between the links and the pulleys. These pulleys are mounted on a 5-in. shaft which is carried on three pedestals equipped with roller bearings. Two of the pedestals can be moved along the shaft to take care of the different positions of the pulleys due to the change of tread

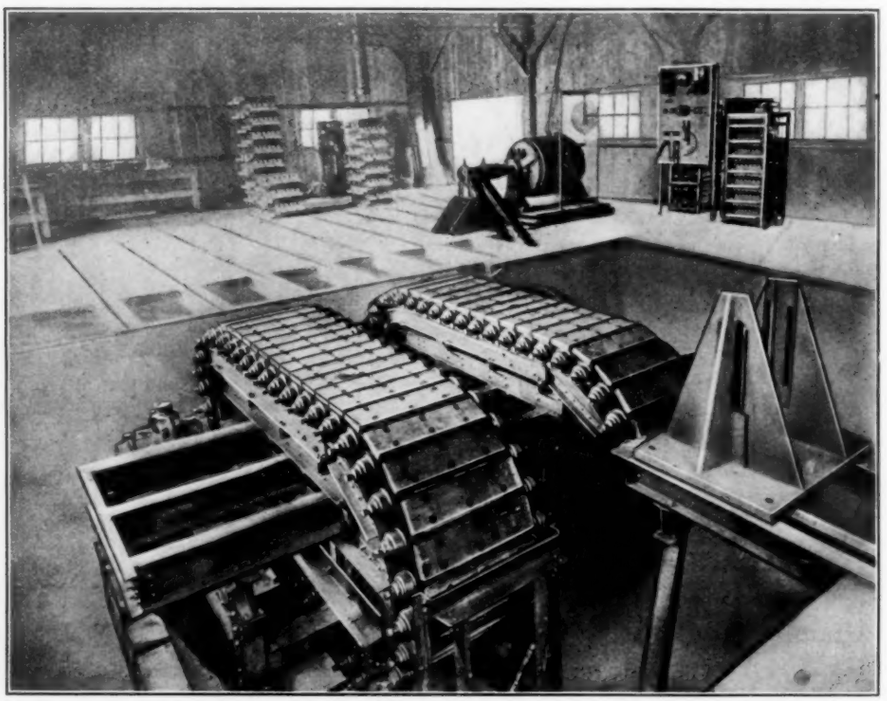


FIG. 2 GENERAL VIEW OF THE PLANT SHOWING THE ELECTRICAL EQUIPMENT

of the tractors. From the end of this shaft the power is transmitted by gears and silent chain to an electric dynamometer located on the main floor of the plant. All bearings in this transmission are either roller or ball type with final connection to the dynamometer by a flexible coupling.

THE ELECTRIC DYNAMOMETER

The electric dynamometer which provides the brake load for the plant is of the Sprague Electric Company's standard design, rated at 100 hp. at 1200 r.p.m. and so wired as to operate either as a generator-dynamometer or as a motor-dynamometer. When operating as a generator-dynamometer the energy generated is absorbed by air-cooled rheostats, the resistance of which can be varied to accommodate the load. The rotating part of the dynamometer is supported on ball-bearing pedestals and by suitable linkwork connected to standard scales. These scales are so connected that the only readings necessary to determine the horsepower being transmitted are the weight on the scales and the revolutions per minute of the dynamometer.

THE DRAWBAR DYNAMOMETER

The drawbar dynamometer is of the pendulum type, the pendulum and the recording arm being carried by a 5-in. drum hung on ball bearings. The pendulum weight and the recording arm are so proportioned that the record made by the recording pen shows 200 lb. drawbar pull for every inch of movement from the vertical position. Tangent to the 5-in. drum, a flexible steel plate 0.025 in. thick is fastened connecting it with a reducing arm by a right-and-left-hand coupling nut. The reducing arm is pivoted on ball bearings and is accurately finished on the end to a radius of 36 in. This arm connects with the drawbar of the tractor at a radius of 12 in., thus giving a reduction for the dynamometer weight of three to one. To the 12-in. arm is attached a flat piece of steel 0.045 in. thick which is connected to the ¾-in. wire rope going to the drawbar of the tractor. This rope passes through a four-wheel guide which can be lowered or raised so that the pull on the tractor will be level at all times and so that there will be no chance for side pull on the dynamometer if the tractor should swing off the center line.

The recording apparatus for the drawbar dynamometer consists of a vertical brass table which can be moved along suitable guides to take care of the different loads. The 10-in. record paper is carried over the table from the lower roll to the upper, the winding mechanism being driven from the main 5-in. shaft of the plant so that the speed of the paper is in exact proportion to the speed of the tractor. Above the recording table are two recording arms which can be moved along a graduated scale, one arm with its pen marking the zero line for the test; i. e., if test is run at 2000 lb. drawbar pull, the zero line would be placed at 1500 or 1800 lb., thus giving a card which would be easy to measure. The second recording arm would be set at the desired load to be carried. This arm will have fastened to it a fine wire with a weight at the lower end which will keep the line plumb and straight at all times. As the operator looks at the recorder, he will see a line which will represent the load he is carrying on the tractor and by this he will be able to keep the electric-dynamometer adjustment correct. Along the side of the table is a sliding electric time recorder which can be set opposite the recording pen so that the time record will correspond to the load record.

A weighing mechanism will be placed under the guiding axle of the tractor so that the changing load on the guide wheel can be measured while the tractor is under load, thus giving a check on the force transmitted to the drawbar.

TYPES OF EXPERIMENTS MADE

The experiments which can be made on a machine such as has been described are of a twofold character:

1 Those made with the tractor to be tested mounted on the moving platform and run in its usual manner, transmitting its energy through the platform, the wheels and the geared train to the generator which acts as a brake.

2 Those in which the engine and main driving shaft of the tractor are connected more or less directly with the generator either with or without the use of the transmission gears, the tractor wheels and the moving platform being "cut out."

The first may perhaps be termed the commercial and the second the scientific test. In the first we have field conditions and field operation imitated. The tractor is run at different speeds and under different loads and the economy or efficiency is determined in the gross, in terms of the drawbar pull and the gasoline consumption.

This would be followed by field or road tests to determine other practical characteristics of the tractor as they are affected by out-of-door conditions. The efficiency of the tractor considered merely

(*Continued on page* 132)

Research and Social Evolution

By C. F. HIRSHFELD[1], DETROIT, MICH.

Research, according to the author of the following paper, is the search for facts, and industrial research is the search for industrial facts. This, he points out, opens a broad and almost unlimited field for the research worker. The value of research lies in substituting methods of assurance based on fact for those of guess which, in the past, have been the bases of judgments made by industrial leaders. Nor is the author pleading alone for what he terms material research but for economic research as well, and most particularly for sociological research, believing that our basic knowledge and control of human relations have not kept abreast of social evolution.

THE study of history reveals a great similarity in the social and economic conditions following wars of great magnitude. There is always a period of topsyturvydom during which radicals of all kinds command large audiences and when individuals and nations act as though they had been relieved suddenly of all historical restrictions and bonds and were free to proceed unhampered in the pursuit of any sort of evolutionary or revolutionary scheme which met their individual or collective fancies.

This period always flows gradually into one in which the necessity of continuing an ordered social life is appreciated by the great majority, and the world, or that part of it affected by the war, settles down once more to the production of wealth and the pursuit of happiness upon a plane and according to methods not greatly different from those in use before the cataclysm.

The real lessons of the war and the lasting results thereof are seldom appreciated until they can be viewed in retrospect, and often through a vista of many years.

The present situation bids fair to duplicate the past. We are apparently just emerging from topsyturvydom and moving toward a more or less ordered existence. We are beginning to appreciate the fact that sociological surgery, like human surgery, has as yet certain limitations. We may perform operations of some sorts without seriously endangering a fairly normal patient, but when the severity of the operation exceeds a certain limit the patient is apt to succumb to shock, even after a most successful operation from the surgeon's viewpoint.

I feel that it is well to bear such facts in mind when discussing research and its application to industry in this country. The public at large seems to believe that industrial research did not exist in these United States before the war; that the phenomenal performance of Germany and her allies was due to the development of such research in Germany; and that we are now about to take up work of this sort in characteristic American fashion, producing over night a dozen or more research laboratories for every one originally possessed by Germany. The facts are that industrial research was fairly common in this country before the war; that Germany's performance, in so far as it depended upon research, was largely based on the utilization of the results of research rather than upon the uncovering of new facts; and that to multiply research laboratories and facilities in this country at too rapid a rate would lead to chaos, waste and business failure instead of acting as a healthy stimulant to a slightly neurotic patient.

We must not expect the war to revolutionize over night our methods of producing and of doing business any more than we can expect it suddenly to "emancipate" labor. The fact that we are now trying to enunciate and codify principles governing the relations between employer and employee which have been in the process of development for decades should not lead us to attribute the principles themselves to the war. The disturbed conditions incident to the war merely serve to focus attention upon the problem. This is a convenient time for taking account of stock before we start out once more in ordered fashion to develop still further.

Similarly, there has been growing in industry during the two decades just past an appreciation of the fact that refined methods of analysis produce results, and the war has simply served to focus attention upon the haphazard way in which industry has adopted and utilized such methods. This is unquestionably the time at which we can best study what we have achieved in the application of industrial research, and at which we can best plan the future development insofar as it is controllable. If you will look over the papers which have been presented before this organization and others of similar type during the past three years, you will discover that some of the best minds in the country are already engaged in just such a task.

Popular Impressions of Research

There is another popular impression which I believe to be basically incorrect. Research is regarded as a name for the efforts of individuals who spend their working hours in physical and chemical laboratories delving into the so-called secrets of nature for the purpose of extracting hitherto hidden facts or formulæ which may be expected to have commercial value. To me this is entirely too narrow an interpretation. I regard *research* as the search for facts, and I regard *industrial research* as the quest for facts which have immediate *industrial* value. Research as now pictured by the multitude may be called *material* research. Industrial research must include many other varieties if it is to achieve its end, particularly economic research and sociologic research. Questions of economic and sociologic types are just as amenable to laboratory treatment as are problems in the proper method of heat-treating a given grade of steel or in the modifications required to take account of mass action in conducting chemical reactions on a commercial scale.

If research be regarded merely as the determination of facts, every department of industry is a proper field for research and possibly can be benefited thereby. In fact, if this definition be adopted, modern research is merely an organized or ordered development of the methods which have been in use for generations. Every executive and every individual in charge of industrial activities has had to make decisions, and, in general, has determined facts on which to base these decisions insofar as that has been possible. Unfortunately the determination of facts in many different lines by one individual and at the rate required to keep pace with the evolution of the industrial world is often impossible, and as a consequence most of our successful executives have fulfilled Elbert Hubbard's definition—they decided quickly and were sometimes right. The marvel is that they were right in such a large proportion of their decisions.

All that we can hope to do by research is to make available for such men the facts upon which to base a greater proportion of their decisions. They will thus have to depend upon judgment, instinct, intuition, or guess, as you like, for a smaller proportion of their decisions, and their work will be just that much nearer to an absolute basis.

The Future of Research

I do not like to pose as a prophet—I prefer to have some honor in my own country if it is obtainable. However, I believe it is patent that our industrial development on its material side is already outstripping the economic and sociologic development required to stabilize it. We are learning to produce in greater quantities and in greater varieties daily, and our attention is so focused on this work that we are giving insufficient thought to the problems of finance, distribution and utilization and to the desires, ambitions and hopes which we are creating.

The literature of the day is so full of articles giving the results of investigations in the field of heat treatment that no manufac-

[1] Chief, Research Dept., The Detroit Edison Co., Jun. Am. Soc. M. E. Presented at the Mid-West Sections Meeting, Indianapolis, Ind., October 24 and 25, 1919, of The American Society of Mechanical Engineers.

turer of steel products can plead ignorance of the fact that exact information is available if he chooses to make use of it. On the other hand, where is that same manufacturer to learn the facts with respect to the advisability of making plant extensions during periods of rising as against falling prices, or during periods of decreasing business failures as against periods of increasing failures? Or where is he to determine facts with respect to the reasons why bonus systems or profit-sharing systems succeed in some places and fail in others? Or where is he to obtain information with respect to the relationship existing between the rate of increase of wages in his plant or in his industry and the rate of increase of living costs? Research in such fields is conducted to a limited extent and certain publications are issued for the purpose of distributing the results, but comparatively few industries seem to have recognized the necessity of applying this sort of research to the problems of industry.

Does it not appear that in the sudden public appreciation of the advantages to be gained from material research we are threatened with a one-sided development which can only lead to trouble unless corrected at the start? Does it not appear desirable for organizations such as this Society to bring to the attention of the public the fact that no decision of any sort need rest on guesswork if facilities for all the necessary types of research are available?

I am not now concerned with the way in which research is to be conducted or financed. For my present purposes it is immaterial whether the federal government pays for *this*, the state government pays for *that*, and the individual producers or a group of producers pay for something else.

I am concerned with developing appreciation of the fact that what we now call research is merely an extension and refinement of methods previously in use; with driving home the fact that material research is only one of the numerous varieties required to continue the present industrial development; and with spreading the doctrine that it is good business to obtain such information as is necessary to enable our industrial executives to base their decisions more largely upon determined facts and to a lesser extent upon so-called judgment. I feel particularly that the continued stable development of the industrial age depends almost entirely upon our ability to bring to our executives those facts which will enable them to stabilize the social structure within which industrialism is contained and has its growth. I see no way of doing this other than by painstaking research along economic and sociologic lines at such a rate as to keep pace with the results attained by the application of material research which industry itself may be depended upon to develop at an ever-increasing rate.

I admit that my program is large, but the problem with which we are faced is large. We of this country, in common with the rest of the civilized world, have developed to a point where the conditions we have created are leading us to question the adequacy and even the validity of what we have regarded as fundamental concepts in the relation of man to man and of nation to nation. Some of us attribute this condition to the rapid development of industry, others to the growth of social and class consciousness, and still others to the continued upward progress of man. Attribute it to what you will, it is a fact that parallel to our development of factories, modern methods of production and of ways and means of bending natural forces and laws to our ends, there has occurred a development in human relations about which we have much less basic knowledge and over which we can exercise correspondingly less control. Is not a rather large program justified by such a set of conditions?

Research and Industrial Wastes

By GEORGE S. HESSENBRUCH,[1] ST. LOUIS, MO.

In the paper which follows the author introduces his subject by calling attention to the lack of interest in research which existed previous to the war. He divides research into two classes which he calls "pure scientific research" and "industrial research," and points out that the latter class has a direct financial return to the industry concerned. He makes a strong plea for research on the subject of industrial wastes and closes his paper by describing a research laboratory now contemplated for pursuing this type of investigation.

UNTIL a few years ago, research in the United States was not looked upon with great favor, except by those few who realized and knew what it had accomplished and what it meant to science. The general opinion among the laity was that only a crank could be interested in research that no special benefit would be derived from it in a commercial way. Its unbounded limits were not recognized by the general manufacturer. No doubt many men in the industries often wished they knew why such and such was the case and what would happen if such and such was done and what might be developed. Research, however, was looked more upon as a kind of inventive genius with which only a few were gifted and not as a science.

Up to that time there were few laboratories devoted to this work and these few were not sufficiently equipped to accomplish very much. Furthermore, their endeavor was mostly along some specific and special line of investigation for a particular industry. But now largely as a result of the world war and the impulse created by it for development along all scientific lines and the consequent industrial activity, manufacturers have come to the realization that activity in research is one of the essentials in the progress of industry, that it has, in many instances proved highly profitable, opened up tremendous fields for industrial endeavor and given them a vast amount of accurate and definite information and data on subjects that previously had only been guess work and chance.

The subject of research can be divided into two distinct classes, namely, "pure scientific research" and what might be called "industrial research." Pure scientific research in most cases does not show very great immediate financial gains and therefore must be undertaken for the pure love of science and knowledge. It requires an investigator of a highly trained mind and peculiar character for the devotion to its cause. He must be of a very analytical trend of mind, possess considerable knowledge, and have unlimited patience and courage. He must be unselfish and have the ability of great concentration. Pure scientific research does not, however, show very great financial gain. The unmeasurable value and importance of this branch is not realized, for with but a few exceptions has a life-long work in this branch brought a commensurate financial return to the one devoting himself to it. Nevertheless, this branch is of the greatest importance and any accomplishment or new discovery in it is of inestimable value. If it were not for pure scientific research we would have no foundation for science. Its discoveries bring forth and determine the fundamentals and principles upon which further development is based and make them available for industrial enterprise and exploitation. At this point the engineer and chemist steps in and applies these new fundamentals and principles, develops them and gradually produces for the world a new piece of apparatus, machinery or process such as in some instances have revolutionized an entire industry. The need of pure scientific research therefore is absolutely essential.

INDUSTRIAL RESEARCH

Industrial research, although highly scientific in principle, might be classed as the branch with the greatest chance of financial returns and for this reason it attracts more attention, as it is more remunerative both to the worker and investigator as well as the investor and industry. It develops known facts still further, and

[1] President, Industrial Engineers Corporation. Mem.Am.Soc.M.E.

Presented at the Mid-West Sections Meeting, Indianapolis, Ind., October 24 and 25, 1919, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

investigates established principles, fundamentals and materials with the sole object in view of making these principles, fundamentals or materials of greater commercial value and more remunerative and available for industrial purposes. The world war and its consequent activities have given this branch of research a great impetus during the last few years in the United States. A great number of the larger corporations are establishing or have established research laboratories. These laboratories are, however, mostly equipped for investigations along the special line of endeavor of the particular corporation. A few private laboratories have been established for the purpose of investigating any subject that may be presented to them by a manufacturer who does not have a laboratory of his own, or who cannot justify the expense of maintaining one, but who can afford to obtain more definite and accurate knowledge on the materials or methods of manufacture pertinent to his particular endeavor. These laboratories undertake this work for a fee and results of value are sometimes obtained; at other times, however, the investigation, although conscientiously carried forward, is bare of results except as to data.

The United States Government has realized the meaning of industrial research and is giving it its support, and many societies and organizations are collecting data as to laboratories, etc., and in this way industrial as well as pure scientific research is gradually receiving more and more attention.

Investigation of Wastes

In industrial research would be included the investigations of wastes. This subject, in the writer's opinion, is one of considerable importance, for in many instances the financial return from the wastes, when properly processed and obtained from the raw materials in a manufacturing plant, have been greater than the return from the actual manufactured article made in this same plant.

Today we are confronted from all over the United States by the cry of increased production. Every manufacturer is striving his utmost to help this movement. In fact, it is the solution or at least an amelioration of many of the evils that threaten us seriously. It is but natural for us to turn toward the utilization of wastes and waste materials, which is the most economical and beneficial way to help this movement. Reducing these enormous wastes or utilizing them in some way or other by suitable processing will not only save our national resources from being depleted more rapidly, but it will also teach the manufacturer to be circumspect. It will reduce costs, establish new industrial undertakings, give employment to more people, open up new channels of commerce, induce capital to invest in new enterprises, increase the production of our soil and finally bring about the one most important status, namely, independence.

One benefit, if we may call it that, arising out of the world war has been that the American manufacturer is today more willing to be convinced in regard to the loss he is incurring daily by the non-utilization of waste materials. A few years ago the writer had the sad experience of being laughed at when putting before several manufacturers a plan by which their waste material would net them a greater return than the article they were producing in their factories. It was only a question of the proper processing of the wastes to make a salable and valuable product, a product that had a big demand and which was being imported. The processing was demonstrated to them, but they frankly said they did not wish to go into the chemical business—they were manufacturers of a certain article and did not care to undertake a new line and would not be interested.

The writer does not wish to minimize the efforts that have been put forth or disparage the good work that has been accomplished by such institutions as the Mellon Institute in Pittsburgh, our own Government laboratories in Washington and Pittsburgh, the Rensselaer Polytechnic Institute and the many private laboratories throughout the country. They have all done good work and are accomplishing a great deal for the benefit of industry and the public in general, but he would like to see a concerted move in the direction of research of wastes and their utilization. In his opinion such research would be of great value, and a brief description of a laboratory for conducting such investigations will doubtless be of interest. Its scheme of operation is so novel and unique as regards the financial returns of the undertaking that the writer feels that every manufacturer, no matter how large or small will be glad to avail himself of the chance to have his waste materials investigated, and developed if possible. It is contemplated that the laboratory will be one of the best-equipped laboratories in the United States, and that the highest possible class of research workers only will be employed. No fees are to be charged and no investigations will be undertaken for a fee, nor will there be any testing of materials. The laboratory is to be devoted purely to wastes and the utilization of wastes. The data collected will be available to any accredited scientist, research worker, or institute free of charge and cannot under any circumstances be utilized commercially except by special sanction of the laboratory management. All processes will be properly patented and the patents will be the property of the laboratory for such disposition as the board of management may deem best advisable. The manufacturer who has sent in the waste will, after proper investigation, be advised in the form of a report of the possibilities. The report will show the investment required for the proposed undertaking, the estimated operating cost, the revenue, the present and future markets and all data such as are required for the sound and proper understanding of the proposed undertaking. If requested, plans and specifications will be furnished for the entire establishment and operation properly started and temporarily superintended. This latter part of course will call for the regular engineering fee as established in the engineering profession. The manufacturer will be assisted in any way it is possible for the laboratory to serve him. In short, every effort will be made to give the manufacturer the full benefit that expert knowledge and investigation in all of the engineering lines can give, the ultimate result in view being to see the establishment of an undertaking that will in some manner or form utilize this waste and bring about conservation.

It is fully realized that a large amount of capital will be required and that the laboratory in all probability will not become self-sustaining for a period of three or four years, but under the scheme as laid out by the originators of the project it is figured that after that time it will become remunerative financially as well as bring about a great benefit to the industries and the public in general. An additional benefit of inestimable value will be the large amount of accurate knowledge and data that will be obtained and placed at the disposal of all mankind, and it stands to reason that hand in hand with industrial research will go purely scientific research, the results of which will be available to all and will be given out for the benefit of science in general.

Following apparently satisfactory test-block studies of a synthetic airplane-engine fuel known commercially as Alcogas and composed of 38 parts alcohol, 19 parts benzol, 4 parts toluol, 30 parts gasoline and 7½ parts ether, the Post Office Department arranged for a test of the fuel under service conditions in the Air Mail.

Mail plane No. 35, a Curtiss Model R4 machine equipped with a high-compression Liberty 12 motor, was assigned for the work, the check plane, flying the opposite trips during the same period with high-test aviation gasoline, being mail plane No. 34, also a Curtiss Model R4 plane, equipped with a low-compression Liberty 12 motor.

Thirty-one trips were flown between New York and Washington, being 218-mile non-stop flights, on the regular air-mail schedule between August 4 and September 19, 1919. The flights made by the gasoline ship numbered nineteen.

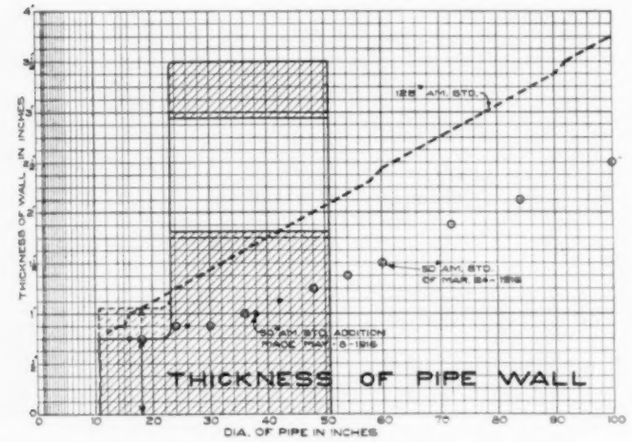
The tests indicate a saving of 3.3 gal. of fuel per hr. in favor of the alcohol fuel. Noting the revolutions per minute, however, the saving is even greater, as alcohol fuel shows 1514.3 r.p.m. as against 1507.8 r.p.m with gasoline. This means that not only is there a saving of 3.3 gal. of fuel per hr., but that 6.5 r.p.m. are gained also by the use of the alcohol fuel.

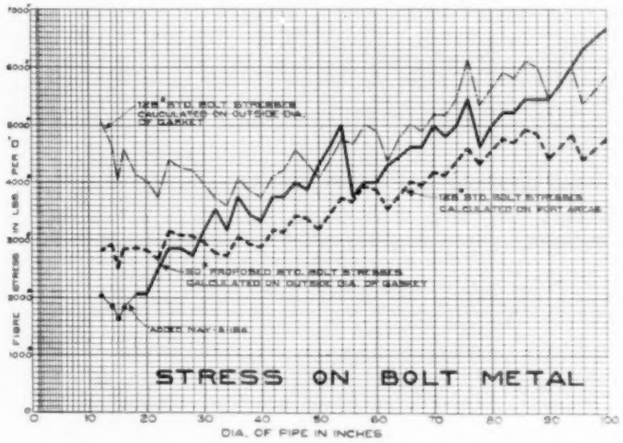
Alcohol fuel also shows a saving in lubricating oil. The average for this fuel was 4.4 qt. per hr. as against 4.98 qt. per hr. for gasoline, or a net saving of 0.58 qt. per hr. This saving is thought to be due to the greater thermal efficiency displayed by alcohol.

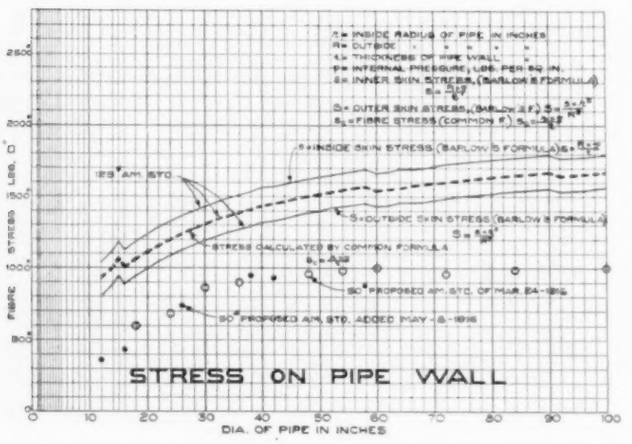
FLANGES FOR CAST-IRON PIPE

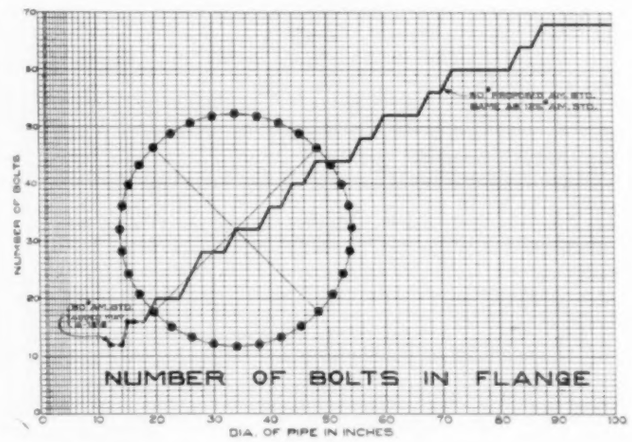
A PAPER by Mr. John Knickerbacker, read before the American Water Works Association last June, invites closer cooperation from the Cast Iron Pipe Makers and the A.S.M.E. Committee on Standardization of Flanges and Pipe Fittings. Mr. Knickerbacker recalls the need for adoption of standard flanges for light cast-iron pipe, and presents diagrams visualizing the different standards and semi-standards now existing for each size.

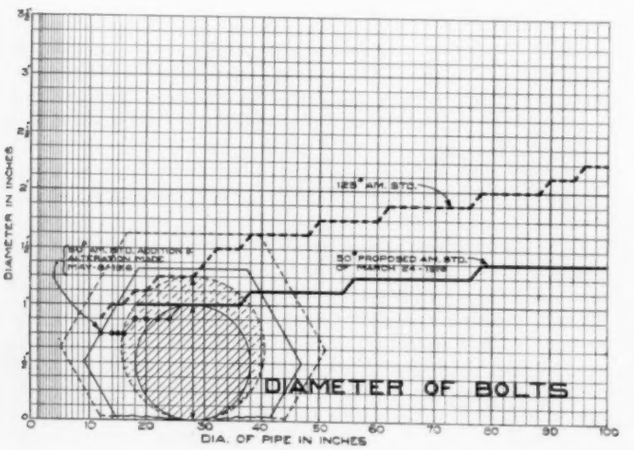
It will be remembered that an A.S.M.E. Committee has had this subject, flange ends for all weights of pipe, under constant consideration since 1892, and it is to the 1918 Report of this Committee that Mr. Knickerbacker especially refers. Therefore the memorandum below by Arthur R. Baylis, Chairman of the A.S.M.E. Committee, is interesting, as explaining the difficulties under which the Committee was obliged to work.

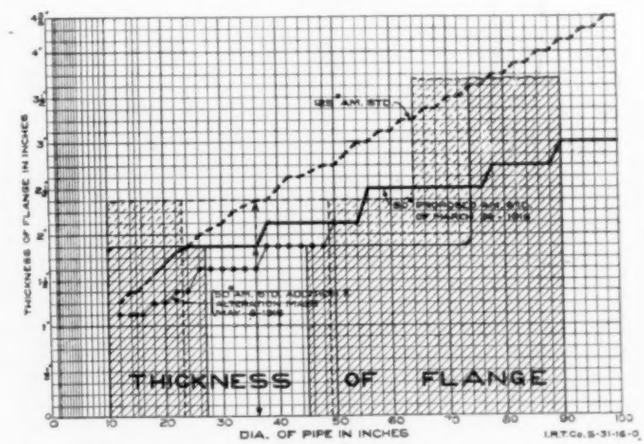

THICKNESS OF PIPE WALL
THICKNESS OF WALL IN INCHES
DIA. OF PIPE IN INCHES
125# A.M. STD.
50# A.M. STD. OF MAR 24-1916
50# A.M. STD. ADDITION MADE MAY 8-1916


STRESS ON BOLT METAL
FIBRE STRESS IN LBS. PER SQ. IN.
DIA. OF PIPE IN INCHES
125# STD. BOLT STRESSES CALCULATED ON OUTSIDE DIA. OF GASKET
125# STD. BOLT STRESSES CALCULATED ON PORT AREAS
50# PROPOSED STD. BOLT STRESSES CALCULATED ON OUTSIDE DIA. OF GASKET
ADDED MAY 8 1916

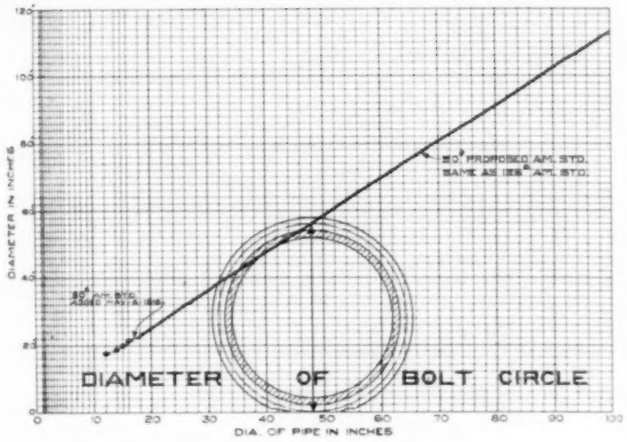

STRESS ON PIPE WALL
FIBRE STRESS IN LBS. PER SQ. IN.
DIA. OF PIPE IN INCHES
125# A.M. STD.
50# PROPOSED A.M. STD. OF MAR 24-1916
50# PROPOSED A.M. STD. ADDED MAY 8-1916

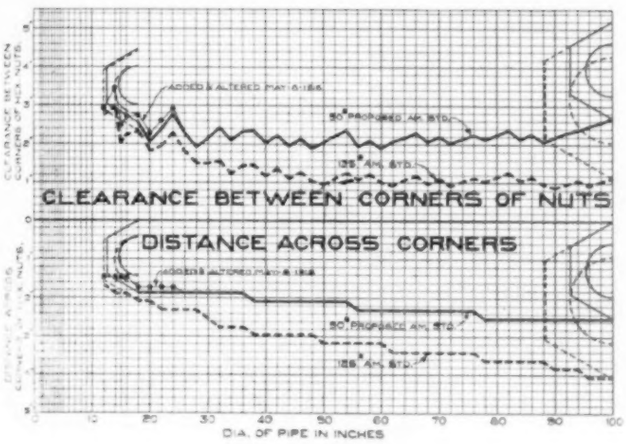

NUMBER OF BOLTS IN FLANGE
NUMBER OF BOLTS
DIA. OF PIPE IN INCHES
50# PROPOSED A.M. STD. SAME AS 125# A.M. STD.
50# A.M. STD. (LATER MODIFIED)

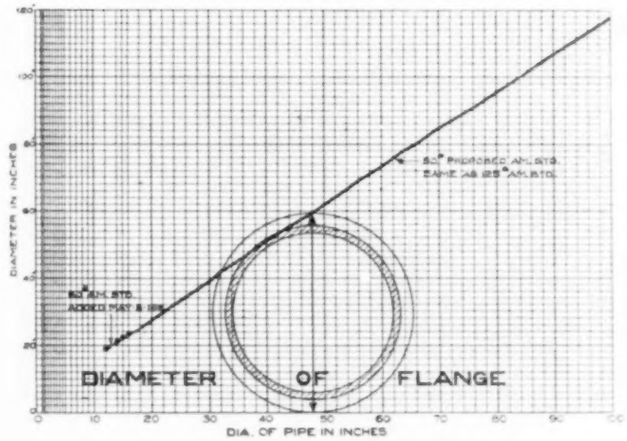

DIAMETER OF BOLTS
DIAMETER IN INCHES
DIA. OF PIPE IN INCHES
125# A.M. STD.
50# PROPOSED A.M. STD. OF MARCH 24-1916
50# A.M. STD. ADDITION & ALTERATION MADE MAY 8-1916

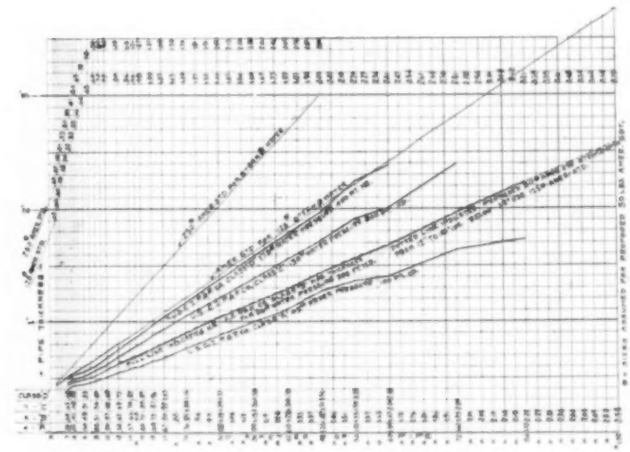

THICKNESS OF FLANGE
THICKNESS OF FLANGE IN INCHES
DIA. OF PIPE IN INCHES
125# A.M. STD.
50# PROPOSED A.M. STD. OF MARCH 24-1916
50# A.M. STD. ADDITION & ALTERATION MADE MAY 8-1916
I.R.T.Co. 5-31-16-Q

CONVENTIONS USED IN DIAGRAMS { ------ INDICATES 125# A.M. STD. ; ——— " PROPOSED 50# A.M. STD. OF MARCH 24-1916 ; -·-·-· " {ADDITIONS & ALTERATIONS MADE IN PROPOSED 50# A.M. STD. OF MAY 8-1916 }









When the A.S.M.E. Committee on Standardization of Flanges and Pipe Fittings first commenced work on the new low-pressure standard, consideration was given to an entirely new set of dimensions proportioned to the specified working pressure and pipe diameters. Other considerations developed which influenced the Committee in arriving at the dimensions set forth in the present 50-lb. American standard.

TABLE 1 PROPOSED LOW-PRESSURE STANDARD FOR END FLANGES, BOLTINGS AND BODY THICKNESS—50 LB. WORKING PRESSURE

Size	Diameter of Flange	Flange Thickness	Bolt-Circle Diameter	Number of Bolts	Size of Bolts	Body Thickness	Size	Diameter of Flange	Flange Thickness	Bolt-Circle Diameter	Number of Bolts	Size of Bolts	Body Thickness
12	19	1 1/16	17	12	3/4	3/4	56	68 1/4	3	65	48	1 1/4	1 1/16
14	21	1 1/16	18 3/4	12	3/4	3/4	58	71	3 1/4	67 1/2	48	1 1/2	1 1/16
15	22 1/2	1 1/16	20	16	3/4	3/4	60	73	3 1/4	69 1/4	52	1 1/2	1 1/16
16	23 1/2	1 1/16	21 1/4	16	3/4	3/4	62	75 1/2	3 1/2	71 1/4	52	1 1/2	1 1/2
18	25	1 3/16	22 3/4	16	3/4	3/4	64	78	3 1/2	74	52	1 1/2	1 1/2
20	27 1/2	1 1/16	25	20	3/4	3/4	66	80	3 1/2	76	52	1 1/2	1 1/16
22	29 1/2	1 1/16	27 1/4	20	3/4	3/4	68	82 1/2	3 1/2	78 1/4	56	1 1/2	1 1/2
24	32	1 1/8	29 1/2	20	3/4	3/4	70	84 1/2	3 1/2	80 1/2	56	1 1/2	1 1/16
26	34 1/2	2	31 1/4	24	1	1 1/16	72	86 1/2	3 1/2	82 1/2	60	1 1/2	1 1/16
28	36 1/2	2 3/16	34	28	1	1	74	88 1/2	3 1/2	84 1/2	60	1 1/2	2
30	38 1/2	2 1/8	36	28	1	1	76	90 1/4	3 1/2	86 1/2	60	1 1/2	2 1/16
32	41 1/2	2 1/8	38 1/2	28	1	1 1/16	78	93	3 1/2	88 1/2	60	1 1/2	2 1/8
34	43 1/2	2 5/16	40 1/2	32	1	1 1/8	80	95 1/2	3 1/2	91	60	1 1/2	2 1/8
36	46	2 1/2	42 1/2	32	1	1 1/8	82	97 1/2	3 1/2	93 1/2	60	1 1/2	2 1/16
38	48 1/2	2 1/2	45 1/2	32	1 1/8	1 1/16	84	99 1/4	3 1/2	95 1/2	64	1 1/2	2 1/2
40	50 1/2	2 1/2	47 1/2	36	1 1/8	1 1/2	86	102	4	97 1/2	64	1 1/2	2 1/2
42	53	2 1/2	49 1/2	36	1 1/8	1 1/2	88	104 1/2	4	100	68	1 1/2	2 1/16
44	55 1/2	2 1/2	51 1/2	40	1 1/8	1 1/16	90	106 1/2	4 1/2	102 1/2	68	1 1/2	2 1/2
46	57 1/2	2 1/16	53 1/2	40	1 1/8	1 1/2	92	108 1/2	4 1/2	104 1/2	68	1 1/2	2 1/2
48	59 1/2	2 3/4	56	44	1 1/8	1 1/16	94	111	4 1/2	106 1/2	68	1 1/2	2 1/16
50	61 1/2	2 3/4	58 1/2	44	1 1/8	1 1/2	96	113 1/2	4 1/2	108 1/2	68	1	2 1/2
52	64	2 3/4	60 1/2	44	1 1/8	1 1/2	98	115 1/2	4 1/2	110 1/2	68	1 1/2	2 1/2
54	66 1/2	3	62 1/4	44	1 1/8	1 1/16	100	117 1/4	4 1/2	113	68	1 1/2	2 1/16

The Committee of Manufacturers on Standardization of Fittings and Valves held an annual meeting on April 19, 1916, at which it discussed a proposed low-pressure standard. It finally authorized a subcommittee to conclude the matter in collaboration with the A.S.M.E. Committee. Their report, which maintains as far as possible interchangeability with the present 125-lb. American standard for flange- and bolt-circle diameters and number and diameter of bolts, is set forth in Table 1.

In determining flange thickness, pipe sizes were separated into groups, a common thickness of flanges being selected for each group, reducing to a minimum the number of stock bolts required, the diameters of bolts being standardized as well.

It does not appear that Mr. Knickerbacker's reference to foundry difficulties on the standardized flanges is well taken, as the permissible variation between thickness of flange and pipe body metal largely depends on the size and shape of the connecting fillet. Good safe castings can be made if the thin metal is gradually tapered into the thick.

In grouping the pipe sizes as mentioned above, it naturally follows that the smallest pipe in each group has a heavy flange while the largest pipe has a light one. When standards are formulated on the basis of interchangeability, with the object of reducing the number of patterns, templets and confusion in construction work, general proportion is of necessity somewhat sacrificed, and it is difficult to determine just where to draw the line. Sizes were selected for minimum thickness of pipe body metal closely following those of the American Water Works Association, class "B" pipe. The new standard is considered ample to meet all physical requirements.

The curves shown here are self-explanatory and a study of them largely explains the standards adopted. These curves were used during Committee discussions in preparing the new low-pressure standard.

Our Committee will be glad to coöperate further with any engineering organization interested in this subject."

(Signed) ARTHUR R. BAYLIS, *Chairman*

A.S.M.E. Committee on Standardization of Flanges and Pipe Fittings.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A. S. M. E.

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulæ or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Apparatus and Instruments A1-20. Electrical Measuring Instruments. An exhaustive paper on the accuracy of commercial electrical measurements requested by the Committee on Instruments and Measurements of the A. I. E. E. has been furnished and submitted to the Chairman of the Committee. It is scheduled for the Convention in February. It discusses the accuracy required, choice, installation, use and maintenance of instruments, conditions of use, features of design, sources of error and improvement. Address Bureau of Standards, S. W. Stratton, Director, Washington, D. C.

Fuels, Gas, Tar and Coke A1-20. Sulphur in Coals. A study of the forms in which sulphur occurs in coals. Bulletin No. 111 of the Engineering Experiment Station of the University of Illinois by A. R. Powell with S. W. Parr. The Bulletin gives the present status of the knowledge of sulphur in coal, the methods used in analyzing the changes in the form of sulphur in the coal, and also conclusions which have been abstracted.

1 The sulphur of coal occurs in four characteristic forms:
(*a*) The resinic organic type.
(*b*) The humus organic type.
(*c*) The pyritic or marcasitic inorganic form, and
(*d*) The sulphate sulphur.

2 Early methods of determining the forms of sulphur gave high results for pyritic sulphur and low results for organic. The methods developed in the Bulletin are more nearly accurate.

3 Some of the sulphur in coal is oxidized to the form of sulphate. Length of time and standing accomplished this.

4 The action mentioned in 3 is hastened by the presence of bacteria or some catalytic agent.

5 The amount of soluble sulphate formed is less than it would be if the amount of soluble iron were taken as a criterion. Some of the oxidized sulphur combined with the organic matter of the coal.

6 When coal is coked the sulphate sulphur is retained by the coke, the pyritic sulphur is partially volatilized, most of the resinic sulphur is left in the coke and the humus sulphur is partially volatilized.

7 The forms of sulphur in the coke were studied but not fully identified.

8 During the coking process secondary reactions between the constituents of the coal and the decomposed sulphur compounds affect the quantity of sulphur retained by the coke.

Address Director of Engineering, Experiment Station, University of Illinois, Urbana, Ill.

Heat A1-20. Hot-Air Pipes with Thin Asbestos. In making simple tests on relative thermo-resistance of layers of asbestos paper when applied loosely and tightly, it was observed that tin vessels containing hot water would cool less rapidly than the same vessels when wrapped tightly with one layer of sheet asbestos 0.013 in. thick. It was found that it was necessary to have asbestos at least 1/16-in. in thickness to be equal in heat conductivity to the bare pipe. Address T. S. Taylor, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.

Metallurgy and Metallography A1-20. Lead and Embrittlement. It has been found that the rate at which intercrystalline brittleness is brought about is proportional to the amount of impurities and to the concentration of acid in the solution in which the lead is placed. Practically all impurities which are found are lodged between the grains. The preferential attack by the corroding agents for these impurities and perhaps for the amorphous intercrystalline cement accounts for the brittleness. Investigations showed that specimens of exceptionally pure lead (99.99 per cent) when immersed in a neutral solution of an acetate for twenty-four days became appreciably embrittled by the formation of minute intercrystalline fissures. No evidence of the existence of allotropic form of lead similar to gray tin could be obtained. Address Bureau of Standards, S. W. Stratton, Director, Washington, D. C.

Properties of Engineering Materials A1-20. Rope. The Action of Acid on Rope with Protective Coatings. Tests of manila rope to determine the effect of asphaltum compound used as a protection to rope against action of muriatic acid show that rope so treated deteriorates as completely as untreated rope. Address Bureau of Standards, S. W. Stratton, Director, Washington, D. C.

B—Research in Progress

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Aircraft B1-20. Propellers. Investigation of airplane propellers in connection with National Advisory Committee for Aeronautics. Prof. W. F. Durand and E. P. Leslie, Stanford University, Cal.

Apparatus and Instruments B1-20. Recording Thermometers. A study of the permanence and accuracy of initial adjustment and sensitivity, of recording thermometers having an upper limit of reading of about 320 deg. fahr., together with a comparative examination of the mechanical excellence and convenience of manipulation and observation of the various types. The tests planned are such as to develop the factors of hysteresis, including pen friction, time lag, fatigue, constancy of zero adjustment and of the elastic properties of the Bourdon tube under frequently repeated temperature cycles. Work of the Sub-Committee on the Permanency and Accuracy of Engineering Instruments, F. J. Schlink, Chairman. Address F. J. Schlink, Physicist, Firestone Tire and Rubber Company, Akron, Ohio.

Apparatus and Instruments B2-20. Oxy-acetylene. An investigation of the apparatus for oxy-acetylene welding and cutting. Method of determining the specific-heat ratio of acetylene passing through acetylene meter has been completed. Bureau of Standards. Address S. W. Stratton, Director, Washington, D. C.

Automotive Vehicles and Equipment B1-20. Radiators. Heat tests of auto radiators. Sheffield Scientific School, Yale University. Address Prof. L. P. Breckenridge, New Haven, Conn.

Friction B1-20. Ball and Roller Bearings. The friction of ball and roller bearings. Sheffield Scientific School, Yale University. Address Prof. L. P. Breckenridge, New Haven, Conn.

Heat B1-20. Heat Transmission in Boiler Tubes. Sheffield Scientific School, Yale University. Address Prof. L. P. Breckenridge, New Haven, Conn.

Heat B2-20. Hot-Blast Heater Experiments. Sheffield Scientific School, Yale University. Address Prof. L. P. Breckenridge, New Haven, Conn.

Heat B3-20. Heat Transfer. Research relating to the development of satisfactory commercial apparatus for the transfer of heat between fluids, vapors and gases and to include a study of the transfer of heat between metal surfaces and fluids of widely varying viscosities. Prof. W. R. Eckert, Stanford University, Cal.

Internal-Combustion Motors B1-20. Modified Diesel Engine. Development of special or modified form of Diesel engine to use kerosene and distillate. Prof. C. N. Cross, Stanford University, Cal.

Machine Design B1-20. Ball Bearings. Development of proper type and mounting of ball bearings for deep-well pumps and centrifugal pumps. S. C. Kyle, Rialto Building, San Francisco, Cal.

Machine Design B2-20. Gear Teeth. Investigations of the wear of gear teeth under loaded conditions, including the influence of a varying intensity of load, materials, tooth forms, and lubrication. Prof. G. H. Marx, Stanford University, Cal.

Machine Design B3-20. Locomotive Packing-Ring Investigations. It has been found that low-sulphur air-furnace iron is more suitable for locomotive packing rings, bushings, valves and piston rings than cupola iron. It appears desirable that the present maximum allowable sulphur limit be lowered and that the minimum transverse strength of castings be slightly increased. It has not been possible to establish a relation between laboratory and service tests. A report on this investigation is now practically complete. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Metallurgy and Metallography B1-20. Steel. Development of steel of suitable grade for pins of buckets on gold-dredging machinery. Pins have diameters from 3 to 7½ in. G. L. Hurst, Union Plant, Bethlehem Shipbuilding Corporation, San Francisco, Cal.

Metallurgy and Metallography B2-20. Electric Furnaces. Improvements in electric furnaces with special reference to the following applications:

a The melting of steel scrap for steel castings.
b The melting of steel scrap and ferroalloys into tool steels.
c The heat treatment of steel castings for annealing or tempering.
d The melting of non-ferrous metals for commercial castings in marine work.

Address C. M. Gunn, 444 Market St., San Francisco, Cal.

Properties of Engineering Materials B1-20. Expansion of Marble. Two slabs of Tennessee marble and one slab of Vermont marble have been exposed to the weather at the Bureau of Standards. During the first three months a considerable change in dimensions was shown, after which the dimensions remained fairly constant One of the Tennessee slabs expanded 0.02 per cent and the other 0.13 per cent of its length, while Vermont marble contracted 0.04 per cent of its length. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

Properties of Engineering Materials B2-20. Tests of Materials before acceptance and to determine cause of failure and strength of electric welds. (Tests 1117-1119-1140-1171-1192-1203-1205-1223 and 1099.) Naval Experiment Station, Annapolis, Md. Address Bureau of Steam Engineering, Washington, D. C.

Properties of Engineering Materials B3-20. Bearing Metals. Tests of bearing metals. (Tests 1101-1114-1145-1092-869.) U. S. Naval Experiment Station, Annapolis, Md. Address Bureau of Steam Engineering, Washington, D. C.

Properties of Engineering Materials B4-20. Repeated Stress and Impact. Investigation of endurance and impact resistance of metals. Test 1220. U. S. Naval Experiment Station, Annapolis, Md. Address Bureau of Steam Engineering, Washington, D. C.

Properties of Engineering Materials B5-20. Magnetic Analysis. The Bureau of Standards is engaged at present on a study of the correlation between magnetic properties of steel and its structure and mechanical properties, and the development, methods and apparatus for the application of magnetic analysis in a practical way. A method has already been developed to determine the degree of homogeneity along the length of a relatively long piece. The quality of heat treatment is also being investigated by magnetic methods. Address Bureau of Standards, S. W. Stratton, Director, Washington, D. C.

Pumps B1-20. Air Chambers. Determination of proper size of air chambers upon reciprocating pumps. No. 1231. U. S. Naval Experiment Station, Annapolis, Md. Address Bureau of Steam Engineering, Washington, D. C.

Railroad Tracks and Signals B1-20. Rail Investigations. The Bureau of Standards is at present making a critical study of available literature for the purpose of classifying rail failures and test data preparatory to initiating an extensive series to discover cause and remedy for such accidents. Bureau of Standards, Address S. W. Stratton, Director, Washington, D. C.

Steam Power B1-20. Steam Power Plants for Automobiles. The Doble laboratories of San Francisco are investigating the development of steam power plants for automobiles under several divisions:

a Systems of combustion using kerosene and cheaper grades of fuel without the formation of soot and carbon deposits.
b The construction of the combustion system to make it automatic and subject to control by the boiler conditions.
c A fuel and fire automatic control.
d The development of a high-pressure boiler of maximum thermal efficiency.
e The development of a new type of steam engine with high economy, flexibility of control and utilization of high-pressure steam with high superheat. Address Doble Laboratories, San Francisco, Cal.

Transmission B1-20. Hydraulic Dynamometers as Transmission Devices. H. B. Langille, University of California, Berkeley, Cal.

Transmission B2-20. Steel Belting. Investigations of the economic possibilities in the use of steel belting as a substitute for leather, with special references to development of satisfactory joint. Prof. G. H. Marx, Stanford University, Cal.

C—Research Problems

The purpose of this section of Engineering Research is to bring together persons who desire coöperation in research work or to bring together those who have problems and no equipment with those who are equipped to carry on research. It is hoped that those desiring coöperation or aid will state problems for publication in this section.

Boilers and Accessories C1-20. High-Capacity Boiler. Design, construction and testing of boilers for high capacities. Address Sheffield Scientific School, Yale University, Prof. L. P. Breckenridge, New Haven, Conn.

Fuels, Gas, Tar and Coke C1-20. Pig-Iron Coke for Making Pig Iron on the Pacific Coast. Address Robert M. Hale, 220 Battery St., San Francisco, Cal.

Heat C1-20. Radiation. Heat radiation from gases to solids at high temperatures. Sheffield Scientific School, Yale University. Address Prof. L. P. Breckenridge, New Haven, Conn.

Heating C1-20. New Method of Heating by Reversal of Thermodynamic Cycle. Reverse a cycle to discharge high-temperature heat and also use discharge from engine driving cycle. Address J. G. De Remer, Rialto Building, San Francisco, Cal.

Hydraulics C1-20. Measurements. The measurement of the flow of fluids. Sheffield Scientific School. Address Prof. L. P. Breckenridge, New Haven, Conn.

Metallurgy and Metallography C1-20. Spelter. A continuous process for producing spelter. See letter from Prof. W. F. Durand in the Research Section of the January number of MECHANICAL ENGINEERING. Address Robert M. Hale, 220 Battery St., San Francisco, Cal.

D—Research Equipment

The purpose of this section of Engineering Research is to give in concise form notes regarding the equipment of laboratories for mutual information and for the purpose of informing the profession of the equipment in various laboratories so that persons desiring special investigations may know where such work may be done.

Sheffield Scientific School, Yale University D1-20. Research Laboratory. The Research Laboratory of the Mechanical Engineering Department of Sheffield Scientific School is equipped as follows:

Heating boilers for using anthracite and bituminous coal
Exhaust fan and heater stacks
Automobile-radiator testing laboratory
Automobile testing drum
Sprague electric dynamometer
Material-testing machines up to 150,000 lb.
Gas-explosion apparatus
150-hp. water-tube boiler
50-hp. two-stage air compressor
Gas producer
Gas and gasoline engines
Steam engines and condensers
Airplane engines of the following makes:
Two 400-hp. Liberty motors
Two 100-hp. Hall-Scott motors
Two 200-hp. Curtiss V-2 motors
Two 150-hp. Hispano-Suiza motors
Two 100-hp. Curtiss OXX motors, and
Two 100-hp. Gnome motors.

Sheffield Scientific School, Yale University. Address Prof. L. P. Breckenridge, New Haven, Conn.

E—Research Personnel

The purpose of this section of Engineering Research is to give notes of a personal nature regarding the personnel of various laboratories, methods of procedure for commercial work or notes regarding the conduct of various laboratories.

Connecticut Research Laboratories E1-20. Through the Research Committee of the Local Sections in Connecticut the names of the following laboratories in the neighborhood of New Haven have been collected. Other lists are to follow:

The Acme Wire Company. Address Dr. R. W. Langley, New Haven, Conn.
American Brass Company. Address J. A. Coe, Waterbury, Conn.
English and Mersick Co. Address S. M. Bradley, New Haven, Conn.
Farrell Foundry and Machine Co. Address Walter Perry, 2nd Vice-President, Ansonia, Conn.
Groton Iron Works. Address H. O. Trowbridge, Groton, Conn.
Greist Mfg. Co. Address H. M. Greist, New Haven, Conn.
Malleable Iron Fittings Co. Address A. E. Hammer, New Haven, Conn.
New Haven Gaslight Co. Address J. A. Norcross, New Haven, Conn.

Scoville Mfg. Co. R. S. Sperry, Waterbury, Conn.
Sargent & Co. Address Henry B. Sargent, New Haven, Conn.
Winchester Repeating Arms Co. Address Edwin Pugsley, New Haven, Conn.

Sheffield Scientific School, Yale University E1-20. The research work of the Sheffield Scientific School is given by the following titles of articles published:

Roll Pressure in Cold-Rolling Brass. W. K. Shepard and G. C. Gerner. Am. Mach., March 1915.
Hardness Tests of Cold-Rolled Steel. W. K. Shepard and C. T. Porter. Am. Mach., Feb. 18, 1915.
Hardness Tests on Brass. W. K. Shepard. Am. Mach., Feb. 8, 1917.
Testing of House-Heating Boilers. L. P. Breckenridge and D. B. Prentice. Jl. A.S.M.E., Nov. 1916.
Experimental Determination of Moisture in Exhaust Steam. E. H. Lockwood. Journal H. & V. Eng., Apr. 1915.
Tests of a Hot-Air-Tube Heating System. E. H. Lockwood and A. C. Staley. H. & V. Magazine, Dec. 1914.
Tests of a Magazine Heater. E. H. Lockwood. H. & V. Magazine, May 1916.
Sampling and Analysis of Producer Gas. P. W. Swain. Jl. A.S.M.E., Dec. 1916.
Practical Testing of Motor Vehicles. A. B. Browne and E. H. Lockwood. Jl. S.A.E., Feb. 1917.
Power Losses in Pneumatic Tires. E. H. Lockwood. Jl. S.A.E., Feb. 1917.

F—BIBLIOGRAPHIES

The purpose of this section of Engineering Research is to inform the profession of bibliographies which have been prepared. In general this work is done at the expense of the Society. Extensive bibliographies require the approval of the Research Committee. All bibliographies are loaned for a period of one month only. Additional copies are available, however, for periods of two weeks to members of the A.S.M.E. or to others recommended by members of the A.S.M.E. These bibliographies are on file in the offices of the Society.

Apparatus and Instruments F1-20. Brightness Measurements. References relating to brightness measurements. A bibliography of one page. Address A.S.M.E., 29 West 39th St., New York.

Leather and Glue F1-20. Casein and Casein Glues. A bibliography of one page. Address A.S.M.E., 29 West 39th St., New York.

Lubricants F1-20. A bibliography of one page on oils and lubricants. Address A.S.M.E., 29 West 39th St., New York.

Transmission F1-20. Gears. Worm and Helical Gears. A bibliography of 18 pages. Address A.S.M.E., 29 West 39th St., New York.

Wastes F1-20. Incinerator Apparatus. The Manufacture of Incinerators. A bibliography of one page. Search 2611. Address A.S.M.E., 29 West 39th St., New York. (See also *Water, Sewage and Sanitation F1-20.*)

Water, Sewage and Sanitation F1-20. Incinerator Apparatus. The Manufacture of Incinerators. A bibliography of one page. Search 2611. Address A.S.M.E., 29 West 39th St., New York. (See also *Wastes F1-20.*)

Water, Sewage and Sanitation F2-20. Underground Water in Arid Countries and Electrical Detectors. Search 2691. A bibliography of one page. Address A.S.M.E., 29 West 39th St., New York.

THE NEW MECHANICAL ENGINEERING LABORATORY, COLLEGE OF ENGINEERING, UNIVERSITY OF ILLINOIS

By CHARLES RUSS RICHARDS,[1] URBANA, ILL.

THE following description of the Power Laboratory of the Department of Mechanical Engineering of the University of Illinois presents the facilities for instruction and research which are afforded by but one of the many laboratories of the College of Engineering, and which are available for the research work of the Engineering Experiment Station. Each department of the College of Engineering is represented in the Engineering Experiment Station and is conducting investigations with funds appropriated for the purpose by the University, or with funds for special coöperative investigations provided by outside interests. The Station is prepared to undertake research work in architecture and architectural engineering, ceramic engineering, industrial chemistry, civil engineering, electrical engineering, theoretical and applied mechanics, mechanical engineering, mining engineering, municipal and sanitary engineering, physics, and railway engineering. The results of completed investigations are published as bulletins of the Engineering Experiment Station, which are distributed free upon request. At present 114 bulletins and 8 circulars have been published.

The following is a partial list of investigations which are being conducted with funds provided by the University: Investigations of the viscosity of glass; of certain ceramic materials and processes; of the drainage of land; of monolithic construction of highways; of riveted steel structures; of the electrical properties of steel alloys; of acid-resisting alloys; of various properties of coal; of the manufacture of gas; of reinforced concrete and other materials of construction; of the explosion of gaseous mixtures; of the gas-engine cycle; of twist drills and the drilling of metals; of coal mining; of the subsidence of land from mining; of heat transmission; of air-steam mixtures; and of the flow of air.

A number of very important coöperative investigations are now in progress, the principal expenses of which are aid from funds provided by the coöperating agencies. These include an investigation of the coking of coal in coöperation with Mr. A. T. Hert of the American Creosoting Co.; an investigation of the stresses in railroad track in coöperation with committees of the American Society of Civil Engineers and the American Railway Engineering Association; an investigation of the stresses in chilled car wheels in coöperation with the Association of Chilled Car Wheel Manufacturers; investigations of problems concerned with coal mining in coöperation with the Illinois Geological Survey and the U. S. Bureau of Mines; an investigation of warm-air furnaces and furnace heating in coöperation with the National Warm Air Heating and Ventilating Association; and an investigation of the fatigue phenomena of metals in coöperation with the Engineering Foundation and the National Research Council. In these coöperative investigations the Engineering Experiment Station provides such laboratory facilities as it may possess, administers the work, and publishes the results obtained; while the cost of special apparatus and other expenses, and the salaries of special investigators, are paid from funds provided for the investigations.

Description of Laboratory and Equipment

This is one of the largest laboratories of its kind in the country with two main floor levels each approximately 120 by 125 sq. ft. in area, exclusive of two small research laboratories 20 by 27 sq. ft. Included in the same building are offices for a staff of from sixteen to eighteen men, three computation rooms, a fairly large lecture room, a stock room, a shop for mechanicians and a modern locker room.

The elevated main floor, Fig. 1, carries the principal equipment and is of heavy reinforced concrete construction designed for a working load of 300 lb. per sq. ft. Numerous light and air wells afford communication between this floor and the lower floor, which is of the same area as the main floor, and sufficiently depressed below grade to give a clear working height, in which there are no beams, of 8 ft. 6 in. These features are all shown in Fig. 1. The roof is of the saw-tooth type with three principal bays running east and west.

STEAM-ENGINE AND TURBINE EQUIPMENT

The principal prime movers installed in the laboratory consist of six engines and two turbines. There has been installed the following equipment, starting at the west end of this group:

A Chandler and Taylor cross-compound engine (9), made up by connecting a 7-in. by 10-in. and a 10-in. by 12-in. simple throttling slide-valve engine, served by a Dean surface condenser.

A 10-in. by 10-in. Ideal, automatic high-speed, non-condensing engine (10), with balanced slide valve and inertia governor.

A 10-in. by 10-in. Ideal, automatic high-speed, non-condensing engine (14), with a piston valve, and a throttling and centrifugal shaft governor, either of which may be used.

[1] Dean, College of Engineering, and Director, Engineering Experiment Station, University of Illinois. Mem.Am.Soc.M.E.

An 8-in. by 12-in. Meyer automatic engine (13), which operates non-condensing.

An 8-in. by 18 in. simple releasing gear, Murray Corliss engine (15), provided with a Dean surface condenser.

A 12-in. by 24-in. simple double eccentric, releasing gear, Allis-Chalmers Corliss engine (17) belted to a 100-kw. bipolar Edison d. c. generator. This engine has a disk speed-changing device on the governor, whereby the speed may be varied from 60 to 120 r. p. m. A Worthington surface condenser, together with reciprocating wet and dry-vacuum and circulating water pumps take care of the exhaust steam from this unit when the engine is operated condensing.

A Kerr single-velocity stage turbine (16) rated at 60 hp., served by the Worthington surface condenser in case the turbine is run as a condensing unit.

(24), capable of delivering 300 gal. of water per min. against a pressure of 150 lb. per sq. ft., and a De Laval two-stage turbo pump (23) having a capacity of 140 gal. per min. when operating against a head of 300 ft.

Main Steam Piping

The high-pressure saturated-steam line is 8 in. in diameter, and enters the laboratory at the northwest corner. It runs underneath the elevated main floor along the west side for the entire width of the laboratory. Near the middle of the laboratory a connection is made by a long-sweep, vertical bend to the main high-pressure saturated-steam header running the length of the main floor. A separator and reducing valve are installed just after the bend at the point where the pipe again becomes horizontal. The steam pressure

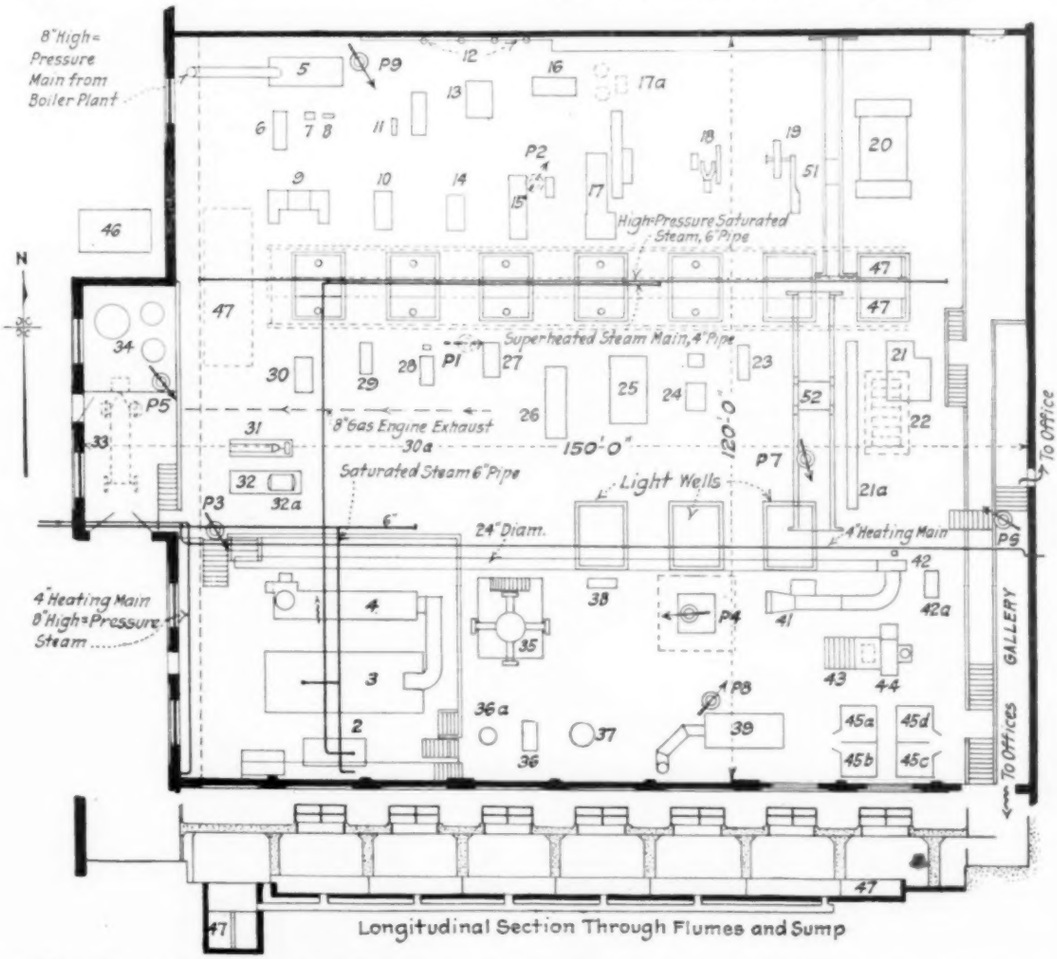


FIG. 1 MAIN FLOOR PLAN OF THE MECHANICAL ENGINEERING LABORATORY SHOWING THE LOCATION OF THE PRINCIPAL EQUIPMENT

A simple slide valve engine (19) designed by Professor Robinson, first professor of mechanical engineering at the University, and built in the mechanical engineering shops of the University.

A large Southwark triple-expansion engine with two direct-current generators (20), given to the University by the Commonwealth Edison Company of Chicago. This machine, formerly installed at the Fisk Street Station of that company, and the preceding unit (19), illustrating the development of the steam engine, will later be placed in a permanent museum.

In the University power house, adjacent to the laboratory, there is available for test work a 100-kw. Curtis turbo-alternator, equipped with the instruments necessary for the measurement of the power output. The turbo-alternator unit has a Wheeler surface condenser, a Wheeler horizontal crank and flywheel wet- and dry-vacuum pump, and a motor-driven centrifugal circulating pump. This condenser equipment is owned by the laboratory.

All engines and turbines, unless otherwise noted, are provided with absorption brakes, either of the Prony or of the rope type.

Equipment for the study of steam calorimeters, the calibration of pressure gages, and the calibration of indicators is located on the north wall (12) and on the adjacent bench.

Pumps

The equipment for test work on pumps consists of a compound Fairbanks-Morse direct double-acting, outside-packed plunger pump

in the steam header is controlled and kept constant by means of the reducing valve.

The piping from the experimental power boiler is so arranged that steam from the boiler may be discharged into the high-pressure saturated-steam main when operating without superheater, or into a second superheated-steam header running parallel to the saturated-steam header and directly underneath it, when operating with superheater. Both saturated- and superheated-steam headers are provided with sliding expansion joints, and are dripped through pot and dump traps.

Flumes and Sump

In order to care for the condensed steam discharged from the engines, surface condensers and pumps, two flumes (47) are provided, running nearly the entire length of the basement. The water may be dropped from the flumes through any one of six circular outlets in the bottom of each flume. These outlets discharge into a sump located at the west end of the flumes and underneath the basement floor. This construction is shown by the longitudinal section through flumes and sump. Provision is made for locating V-notch weir plates in the flume so as to measure the amount of water flowing.

At present the water from the sump is discharged to waste by means of an electrically driven centrifugal sump pump. The discharge will eventually be into a cooling tower (46), which is soon to be built.

Small Power Plant Group

In order to demonstrate the operating characteristics and relation of the equipment of a steam plant, a small power plant has been erected. This plant consists of an Erie City hand-fired portable type of firebox boiler (5), rated at 25 boiler hp. capacity, operating under natural draft with a steel stack 20 in. in diameter, and 40 ft. high; a 7-in. by 10-in. Atlas steam engine (6), with a throttle governor, the output of which is absorbed by a Prony brake; a Cochrane open feedwater heater (7) of 50 boiler hp. capacity; an American single-acting simplex boiler-feed steam pump (8); and a Keystone water meter for measuring the amount of feedwater used.

Power Boiler for Experimental Purposes

The power boiler group (2), (3) and (4), consists of a Heine horizontal water-tube boiler (3) of 210 boiler hp. rated capacity,

Fig. 2 Flumes, Lower Floor. See Fig. 1, P-1

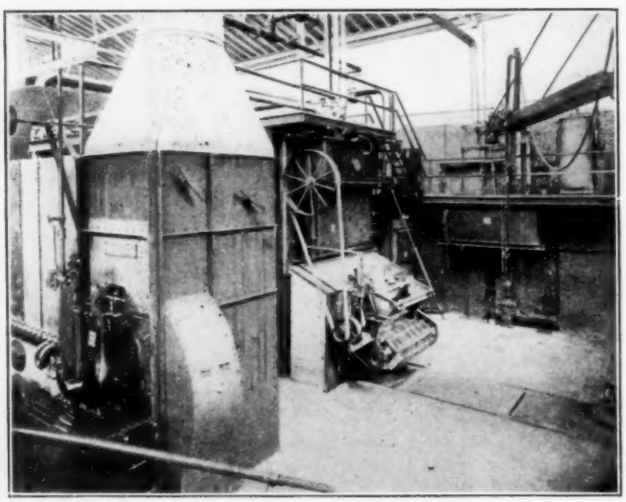


Fig. 3 Power Boiler Group. See Fig. 1, P-3

equipped with a Green chain-grate stoker having a grate area of 38.2 sq. ft. and belt driven from a small vertical steam engine; a separately fired Foster superheater (2), having 3400 sq. ft. of superheating surface capable of superheating 4500 lb. of steam per hr. through 200 deg. fahr., and a Sturtevant economizer and induced-draft fan (4), which draws the flue gases through the economizer when the economizer is being used, or through a bypass underneath the economizer when the dampers are thrown to cut the economizer out of service. The gases are discharged by the induced-draft fan into a steel stack 36 in. in diameter and 45 ft. high. In order to drive this fan, a small vertical Sturtevant steam engine is coupled directly to it. This engine also drives the mechanism for moving the scrapers which clean the economizer tubes.

A feedwater tank (1) is located near the boiler into which tank the feedwater is discharged, after having been measured in a calibrated tank located directly above the feedwater tank. The feedwater can be delivered to the boiler from the feedwater tank either by a direct-acting boiler-feed pump located on the main floor directly underneath the feedwater tank, or by means of three injectors located directly above the feedwater tank.

The arrangement of the boiler group is such that the operation of the boiler may be studied in any one of three ways: the boiler operating without either the economizer or the superheater, the boiler operating with either economizer or superheater, or the boiler operating with both economizer and superheater.

Heating and Ventilation

As already indicated, the south bay is largely devoted to work in the field of heating and ventilation. A four-unit steam-radiator testing plant (45-a,b,c,d) has been conveniently arranged for comparing the coefficient of heat transmission of various types of direct steam radiators. Steam can be supplied at any desired constant pressure so that simultaneous tests may be run on the radiators located in the four enclosures, and their comparative efficiencies and transmission coefficients easily determined.

An experimental hot-blast heating unit has been completely equipped for a variety of tests. The heater proper (43) consists of six sections of 1-in. pipe coils, each section containing 507 equivalent lin. ft. of pipe, making a heater equal to approximately 3000 sq. ft. of direct radiation. The condensation from each section can be weighed separately and the air flow and temperature rise measured, so that the effect of any air velocity on the heat transmission coefficient is readily calculated. A Buffalo Forge Company's steel-plate fan (44) with a 100-in.-diameter fan wheel is operated by a direct-connected 6-in. by 6-in. vertical steam engine for drawing air through the unit. Pneumatically controlled bypass dampers control the flow of air through or under the coils.

Near the above heater stands a Warren Webster & Company's

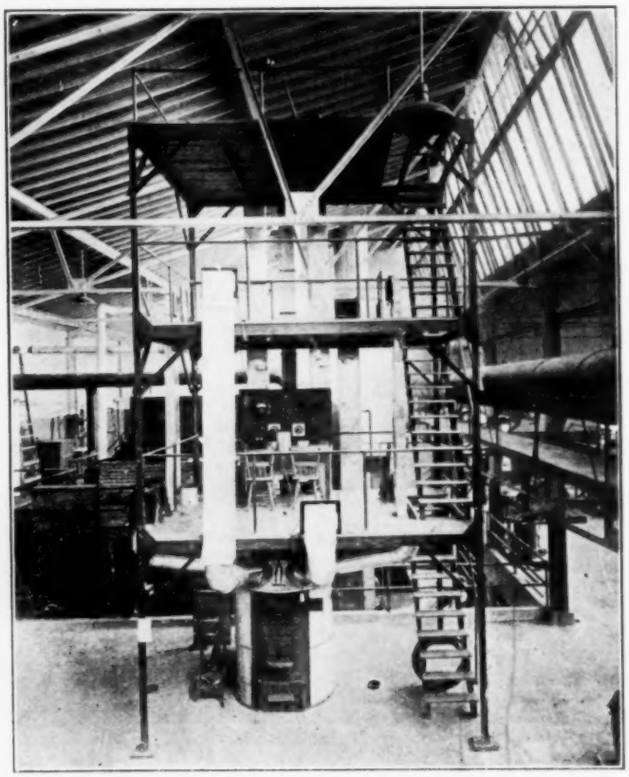


Fig. 4 Warm-Air-Furnace Testing Plant. See Fig. 1, P-4

air washer (41) of the humidifying type. This is equipped for temperature and humidity control with a Powers water thermostat operating on the steam and water mixer in the washer tank. Any desired initial air temperature can be secured by the Vento tempering coil which is under the control of a Johnson Service Company's duct thermostat. The washer has a capacity of 3000 cu. ft. of air per min. at a free-area velocity of 500 ft. per min.

A No. 4 single-inlet Sirocco multiblade fan (42) is used to draw air through the above washer. This fan is mounted on a gallery and discharges the air into a metal duct 24 in. in diameter and 100 ft. long. Complete facilities are provided for making traverses of this duct at any point, so that accurate data on the air volume handled and coefficient of duct friction may be determined. By using the first 40 ft. of the duct and disconnecting the air washer, rating and efficiency tests of the Sirocco fan are easily made. The fan is operated by a Sprague electric dynamometer (42-a) of 10 to 25 hp. capacity with a speed range of from 1000 to 4000 r.p.m.

A heat-transmission testing plant (40) for finding the heat loss through various building materials has been set up in the form of a standard box with special walls 8 in. thick and 6-ft. by 6 ft. sides. An electrical heating element and numerous thermocouples at all surfaces supply and measure heat input and temperature gradients respectively. This plant has been used regularly, but has not yet been inclosed, as indicated on plans, to completely protect it from all disturbing influences.

A Kewanee down-draft brick-set smokeless steam boiler (39) with water-tube grate is the principal item in the heating-boiler equipment. This boiler is rated at 1900 sq. ft. of radiation with a water-grate area of 7.1 sq. ft. It is equipped for securing very complete data on efficiency and capacity, and can be fed with condensation from the hot-blast unit described above. The boiler was given to the University by the Kewanee Boiler Company.

A small Arco cast-iron round steam-heating boiler (37) rated at 800 sq. ft. of radiation is also included in the boiler equipment. This boiler has a grate area of 4.12 sq. ft. and was made by the American Radiator Company. In addition to the above, there is a Mercer cast-iron sectional steam-heating boiler (36) of 1275 sq. ft. rated capacity. This boiler is of the header type with a grate of 6 sq. ft. area, and was made by the H. B. Smith Company. The last two boilers were used in securing data for Bulletin No. 31 on House Heating Boilers.

A single-sweeper vacuum cleaning machine (38), made by the American Rotary Valve Company, has been mounted in portable fashion to facilitate the testing of its efficiency, amount of air handled, and vacuum required for cleaning purposes. The exhauster is of the rotary, double-impeller type, belted to a 1-hp. motor.

Probably the most elaborate feature of this section of the laboratory is the warm-air-furnace testing plant (35) and its auxiliaries. This equipment has been erected for the purpose of measuring the efficiency and capacity of warm-air furnaces under conditions of service with leaders, stacks and registers at three floor levels. In this way it is not only possible to test the complete system, but also to determine the losses in various parts of a system when in operation.

In order to secure the necessary data, an elaborate system for temperature measurement, using thermocouples, has been worked out so that all readings can be taken at a central point. The air flow is measured at inlet and outlets by specially calibrated anemometers. These anemometers are checked before each test in two calibrating plants which reproduce the conditions of service in all details, such as temperature of air, effect of register faces, movement of anemometer, and velocity of flow. This calibrating system is probably the most unique feature of the tests.

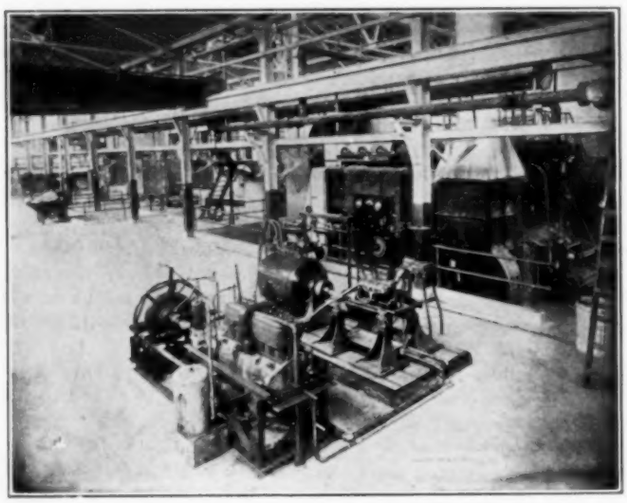


FIG. 5 THE AUTOMOBILE ENGINE-TESTING PLANT. SEE FIG. 1, P-5

A small auxiliary plant equipped with a single leader and stack has also been set up for studying all types of leader and stack construction. This research work is being carried on in coöperation with the National Warm Air Heating and Ventilating Association.

AIR COMPRESSOR

The air-compressor equipment consists of an Ingersoll-Sargent compound steam and two-stage air compressor (25) having a rated capacity of 300 cu. ft. of free air per min. at a speed of 120 r.p.m. The rated delivery pressure is 80 to 100 lb. per sq. in. gage. The air cylinders are 12¼ in. and 18¼ by 12 in. and the compressor is driven by a direct-connected steam engine having cylinders 12 in. and 22 in. by 12 in. The air from this compressor is delivered to a receiver on the lower floor of the laboratory, and from this receiver it is discharged into the atmosphere through a gage box and orifice. This box has two compartments, each similar to the one used by R. J. Durley in his experiments in the measurement of air. The machine is equipped with revolution counters, reducing motions and other apparatus requisite for making complete tests.

REFRIGERATION EQUIPMENT

The refrigeration plant consists of a York ammonia compression machine (21) and a Vogt absorption machine (21a). A freezing tank, with a capacity of 35 cans, each holding 100 lb., is built into the lower floor, and arranged so that the brine from either machine may be circulated through it for the purpose of making ice. This tank is of waterproof concrete construction, is built flush with the floor level, and is heavily insulated by means of cork blocks.

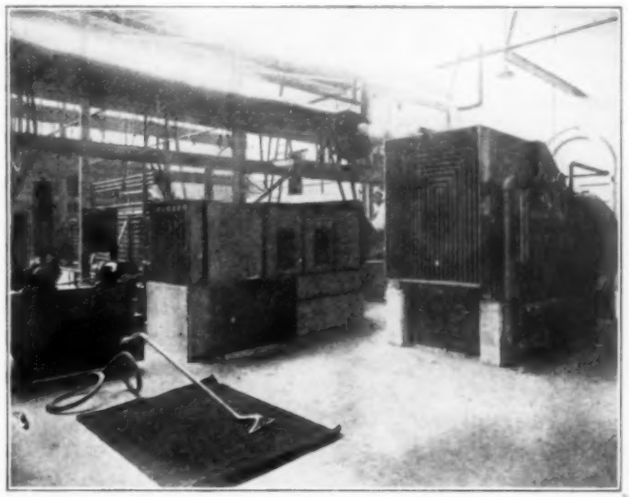


FIG. 6 HEATING AND VENTILATING EQUIPMENT, SOUTH TO NORTH. SEE FIG. 1, P-8

FIG. 7 MAIN ELEVATED FLOOR, NORTH TO SOUTH. SEE FIG. 1, P-9

The York machine (21) is of the vertical single-acting duplex-compressor type, having cylinders 7½ in. in diameter and a stroke of 10 in. It is driven by a 11½-in by 10-in. Corliss engine and has a capacity of 10 tons of refrigeration per 24 hr. A set of cooling coils and a reheater is arranged on the lower floor of the laboratory, thus permitting the refrigeration capacity to be determined without the necessity of making ice, and eliminating the inconvenience of running long tests.

The Vogt machine (21a) has a capacity of 10 tons of refrigeration per 24 hr. It is of the standard commercial type modified slightly to adapt it to testing purposes. There are two anhydrous ammonia receivers equipped with gage glasses, thus facilitating the measurement of the anhydrous ammonia circulated. The piping to the absorber, exchanger, weak-liquor cooler, and rectifier is arranged so that the cooling water may be circulated through them in any way deemed desirable for experimental purposes. The steam used for heating the strong liquor may be taken either from the low-pressure steam main

(*Continued on page* 144)

ENGINEERING SURVEY

A Review of Progress and Attainment in Mechanical Engineering and Related Fields, as Gathered from Current Technical Periodicals and Other Sources

SUBJECTS OF THIS MONTH'S ABSTRACTS

EFFLUX OF GASES THROUGH SMALL ORIFICES
CONSTANTS OF RADIATION OF UNIFORMLY HEATED ENCLOSURE
ATMOSPHERIC ABSORPTION OF HEAT
MALLEABLE IRON, PHYSICAL TESTS
PULVERIZED COAL IN OPEN-HEARTH PRACTICE
TIDAL-POWER DEVELOPMENT AT HOPEWELL, N. B.
LUBRICATION
WORM GEARING, IMPROVED
CUTTING POWER OF LATHE TURNING TOOLS
DIAMOND WIREDRAWING DIES
LONGITUDINAL INTERNAL STRESSES IN STEEL CYLINDERS
PUDDLED-IRON PRACTICE
ABSOLUTE UNIT OF TIME
RIPKEN AUTOMATIC DRIFTING VALVE FOR LOCOMOTIVES
FUEL OIL, USE AND HANDLING
SALT PRECIPITATION BY REFRIGERATION
STAYBOLT DEFLECTION IN LOCOMOTIVE BOILERS
MULTI-STAGE NOZZLE STEAM TURBINES
MOLLIER AIR REFRIGERATING MACHINE WITH MULTI-STAGE NOZZLES
SPECIFIC HEAT OF AIR AT VARIOUS TEMPERATURES
ABRASIVE WHEELS AND THEIR TESTING.

BUREAU OF STANDARDS

THE EFFLUX OF GASES THROUGH SMALL ORIFICES, Edgar Buckingham and Junius David Edwards. This paper contains a theoretical discussion of the results of experiments made during an investigation of the effusion method of determining gas density; and it is a sequel to the paper in which that investigation has already been described by one of the present authors. The effects on effusion of viscosity and thermal conductivity of the gas are studied, and formulæ for representing these effects are developed and compared with the observed facts. A physical interpretation is thus obtained for the most striking of the apparent anomalies observed in the behavior of gases flowing through very small orifices such as are used in apparatus for determining density of effusion. The mathematical work was, unavoidably, too cumbersome for satisfactory abstraction. The resulting agreement of the theory with the observations is exhibited graphically. It is fairly satisfactory but not perfect, and its imperfections suggest the directions in which further experiments should be made. (Abstract of *Scientific Paper No. 359, U. S. Bureau of Standards*, e)

THE CONSTANTS OF RADIATION OF A UNIFORMLY HEATED ENCLOSURE. Experimental data are given on atmospheric absorption. The paper gives also a recalculation of the coefficient of total radiation of a uniformly heated enclosure, or so-called black body, giving a value of

$$\sigma = 5.72 \times 10^{-12} \text{ watt cm}^{-2} \text{ deg}^{-4}$$

The effect of atmospheric absorption is discussed, and the conclusion arrived at is that, if corrections are made for atmospheric absorption, the value recently obtained at Naples is close to the average value, viz.,

$$\sigma = 5.7$$

In the second part of the paper the present status of the constant of spectral radiation is discussed. (Abstract of *Scientific Paper No. 357, U. S. Bureau of Standards*, by W. W. Coblentz, t)

ENGINEERING MATERIALS

PHYSICAL TESTS OF MALLEABLE IRON. At the recent annual meeting of The American Society for Testing Materials, W. R. Bean, of the Eastern Malleable Iron Co., Naugatuck, Conn., presented data showing the possibility of making malleable iron in heavy sections.

Test pieces were cut from a malleable-iron bar 3 in. by 3 in. in section. These test pieces ran lengthwise with the bar, and were so selected that every portion of the cross-section was represented.

From data of these tests it would appear that the test pieces from the corners of the bar were the strongest as well as the most ductile, ranging slightly over 45,000 lb. per sq. in. in tensile strength.

The weakest samples were from the center of the bar, but even they gave a tensile strength of 39,859 lb. per sq. in., which is quite good for iron in the center of such a heavy section of metal.

Data showing the effect of the skin on the strength of malleable iron were also given, and would indicate that there was little difference in minimum tensile strength or other test values before or after machining.

Interesting data are also presented on annealing of cast iron and the effects of carbon conditions. (*The Foundry*, vol. 47, no. 337, Dec. 15, 1919, pp. 906-908, 6 figs., e)

FUELS AND FIRING

What 18 American Steel Plants Say About Pulverized Coal in Open-Hearth Practice

PULVERIZED COAL IN OPEN-HEARTH PRACTICE, W. H. Fitch. A review of the experience of eighteen American steel plants. From this review it would appear that pulverized coal was applied in some cases deliberately and in other cases under the urgency of necessity, chiefly actual or threatened lack of the fuel regularly used.

Practically all of the furnaces under investigation were designed to use producer gas, though some of them passed to other fuels such as natural gas or fuel oil even before an attempt was made to burn powdered coal.

In some of the cases the results with powdered coal were decidedly unsatisfactory. Apparently this was due chiefly to the lack of proper design of the furnaces, although in the case of acid steel there appeared to be fundamental defects with pulverized coal.

In general, however, the investigation appears to have shown that pulverized coal is quite a proper fuel for open-hearth furnaces, provided only the conditions of its use are right.

In this connection the experience of plants G, H and I is illuminating. During the winter of 1916 there was a scarcity of natural gas, and the management became interested in finding a substitute, fearing the necessary supply of gas would not be obtainable. A careful investigation of the situation was made and an engineering company specializing in this line of work was given a contract to install pulverizing machinery, distributing systems and furnace fixtures.

As it was felt that furnace design was the principal factor in determining the success of operation with a new fuel, it was decided that it would be best to make as little change as possible to begin with, allowing for the result of experience of applying coal dust to one furnace to point the way and nature of changes necessary.

Considerable trouble in various ways was experienced at first, but due to a number of furnaces being in use it was possible to make minor changes at various times when the furnace was down for repairs, and in this way different arrangements of checker brick, ports and roof were experimented with. Changes that could be made easily to the furnace above the charging floor were lim-

ited, due to the necessity of making very radical changes in steel work, which, for the time being, were prohibitive.

Eventually, the slag chamber was found to be a very important factor, as its capacity decided the number of heats that could be made without stopping the furnace for cleaning.

TABLE 1

	Producers		Pulverizers	
Power	75 kw. x 24 hr. x 1 c.	$18.00	122 kw. x 24 hr. x 1 c.	$29.28
Gas and ash man	18 x 8 x 60 c.	86.40		
Dryer man			3 x 8 x 60 c.	14.40
Pulling man			3 x 8 x 60 c.	14.40
Unloading coal	240 x 2 c.	4.80	180 x 2 c.	3.60
Repairs	240 x 10 c.	24.00	180 x 10 c.	18.00
Steam		44.40		
Circulating water	200 gal. per min.	4.80		
		182.4		79.68
	$182.4 ÷ 240 = $0.76		$79.68 ÷ 180 = $0.45	

Several other companies have had the same experience with reference to the importance of the proper design of the slag chamber. It appears that the desirable design should embrace a slag chamber of large cubical content, having a removable bottom, and affording the gases an opportunity of expanding and precipitating the heavy oxides of molten ash. Also, there should be a regenerative chamber of large volume and provided with observation and cleaning doors at each end of the furnace, the checker brick being assembled to provide vertical flues of comparatively large area and the waste gases passed through the boiler.

The most economical results, however, are obtained by returning all of the waste heat available to the furnace, and a design of the furnace that will provide for the accumulation and removal of fine ash after passing through the slag chamber will have the effect of cleaning the gases before they enter the regenerative chamber. It will then be possible so to arrange the checker brick to form flue areas that will absorb the maximum quantity of heat from the outgoing gases and permit the incoming live air to be heated to the desired temperature.

There have been accidents and casualties in the use of pulverized coal, but the number is said to have been small and in many instances they were the result of negligence on the part of the operator.

As regards the comparative value of pulverized coal and gasified coal, Table 1 would appear to show that on the whole pulverized coal is cheaper. (*The Iron Age*, vol. 104, no. 26, Dec. 25, 1919, pp. 1323-1328, *gc.A*)

HYDRAULIC ENGINEERING

Proposal to Develop 90,000 hp. from a Tidal-Power Plant in Canada

PROPOSED TIDAL-POWER DEVELOPMENT AT HOPEWELL, N. B. Data of a proposed development of unusually large size to be located at Hopewell, New Brunswick, where it is believed conditions are especially favorable to such an undertaking.

The layout can be seen from Fig. 1, which is a roughly sketched map of the confluence of the Petticodiac and Memramcoke Rivers, which empty themselves into the tidal source, in this case the Shepody Bay.

There are two main dams proposed, the western one 49,000 ft. long and the eastern one 48,000 ft. long, and also a short wing dam of 900 ft. dividing the high-level from the low-level basins. It is proposed to have a highway and trolley line running over these dams to facilitate shore-to-shore communication.

The western dam would be provided with automatic flap gates opening upstream, which would allow the high-level basin to be filled at each high tide, and at the eastern dam there would be similar gates opening downstream to allow the low-level basin to empty on every ebb tide.

The cycle of operation beginning with low tide would be as follows: The water from the spillway would be discharged directly into Shepody Bay, which is the tidal supply, with the gradually decreasing head as the tide rises. At the proper time the attendants close these gates and open other gates, allowing the spillway discharge to enter the low-level basin, into which the spillway will continue to discharge for about 6½ hr., that is, through the last 3½ hr. of flood tide and through the first 3 hr. of ebb tide, after which the cycle will be reversed and start all over again. During the flood tide the high-level basin is replenished and by this means continuous 24-hr. operation is secured.

In order to determine the commercial possibilities of a given location for tidal-power generation, it is the range of the tide and not the actual rise which has to be considered, and to determine this an analysis of the ranges which will occur in the course of a year is necessary. At Hopewell about 15 per cent of the time the tides exceed 42 ft. range, and for about the same percentage of time there are sub-normal neap tides ranging less than 32 ft.

The initial installation is proposed to be about 90,000 gross hp., for which it is believed there is ample water available. By steadily improving the ratio of the two basins, it is believed that the power output could be increased up to 200,000 hp. without making the level drop exceed the limit of 6 in. per hr. (*The Electrical Times*, vol. 56, no. 1469, Dec. 11, 1919, pp. 462-463, 2 figs., *d*)

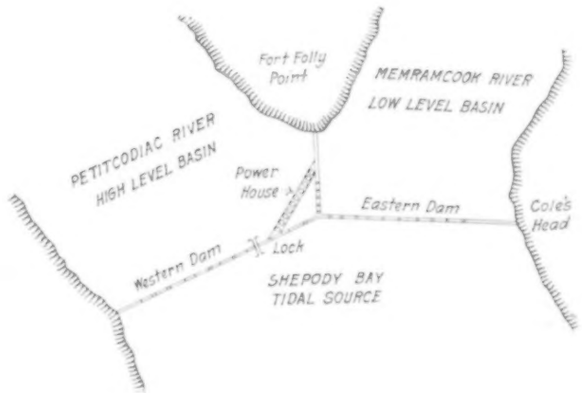


FIG. 1 LAYOUT OF THE PROPOSED TIDAL-POWER PLANT AT HOPEWELL, NEW BRUNSWICK

LUBRICATION

The Physico-Chemical Phenomena Governing Lubrication

OILINESS OF LUBRICANTS—WHAT IT IS AND WHAT IT DOES

LUBRICATION. Abstract of a discussion on this subject before the Physical Society, London, in connection with a paper by R. Mountford Deeley on Oiliness and Lubrication.

The significant feature about this discussion is the large attention paid to the physico-chemical phenomena in connection with lubrication. In introducing the discussion, Dr. F. E. Stanton gave a brief account of the history of the physics of lubrication from the researches of Beauchamp Tower in 1833 to the work of Somerfeld and A. G. M. Michell and the later investigations of Harrison and Hyde.

An abstract of Deeley's paper will be given later. Among available data it appears that it presents a description of the apparatus used for testing oiliness at the National Physical Laboratory at Teddington, and data obtained therewith.

In discussing this paper L. Archbutt pointed out that the following two conditions should be clearly distinguished in considering lubrication problems: (1) Cases where the two solid surfaces were completely separated by a film of oil as with properly fitted journals revolving at high speed and abundantly fed with oil; and (2) cases where owing to the shape and condition of the surfaces, low speed, high pressure or inadequate oil supply, the oil film could not form completely or became broken so that the solid surfaces came into contact.

In the first instance the friction was entirely due to the viscosity of the oil and the theory of Reynolds and the study of physical and chemical characteristics of an oil could be used as guides. In the second case the circumstances were entirely different and trials had to be relied on. Oils alike in viscosity might have different friction-reducing values and it is here that the property termed "oiliness" becomes very important.

Mr. Deeley's machine seems likely to give a means of measuring that oiliness and his view that oiliness enables the oil or some constituent of it to combine with the surface and form a lubricating film is in accord with Langmuir's view.

L. Archbutt recently found that under the same conditions of speed and pressure and with the same oil, bearings of white metal would carry double the load of bronze bearings without increase of friction.

On Langmuir's theory the molecules of the oil and solid were held together by residual or secondary valencies, and the more chemically active the lubricant, the more firmly it would be attached.

In this connection, the behavior of acids in lubricants is quite significant. Free acids have so far been considered injurious in lubricants, because they corroded and formed soaps thickening the lubricant in the presence of moisture.

Southcombe found, however, that the very restricted amount of fatty acids, while of no advantage in the first of the two cases above referred to, had a very remarkable effect in the second of the two cases, that is, the one in which the surfaces of journal and bearing come into contact.

Experimenting with a Thurston machine at low speed, 7 ft. per min., and pressure of 270 lb. per sq. in., Mr. Archbutt had found that 1 per cent of the fatty acid of rape oil added to a mineral lubricant lowered the coefficient of friction from 0.0047 down to 0.0033, and that 2 per cent of the acid did not effect any further lowering. Of neutral rape oil 60 per cent was required to produce the same effect; it was in that respect rather fortunate that commercial rape oil always contained some fatty acid. The important point was that a small percentage of fatty acid improved the lubricating power of a mineral oil as much as a large percentage of fatty oil. But it was also noteworthy that he had found a perfectly neutral rape oil to give lower friction than a mineral oil of the same viscosity. In comparative tests made with a commercial rape oil of 2.4 per cent of fatty acid R, with a perfectly neutral oil R_1 prepared from R, and with a mineral oil M of the same viscosity, he had obtained the following friction coefficients: $M = 0.0078$, $R = 0.0050$, $R_1 = 0.0045$. These results, if confirmed, would suggest that the oiliness or lubricating efficiency of the unsaturated molecules of the neutral rape oil was nearly as great as that of the free fatty-acid molecules, but that the acid molecules were much more active in their influence on the hydrocarbon molecules of the mineral oil. The size of the molecules and the thickness of the molecular layer would be important factors, and Langmuir's researches, referred to in an earlier paragraph, seemed to throw considerable light upon the subject.

Dr. H. S. Allen, of Edinburgh University, in a note on Molecular Layers in Lubrication, again referred to Langmuir's theory of films. This theory might be expressed in its application to lubrication as follows: The metal covers itself with a layer of oil one molecule thick resembling a piece of velvet firmly glued to the metal with the pile outward, and two such velvet-clad surfaces would glide over one another with but little friction. If this be so, oiliness would depend neither on viscosity nor on compressibility, but on chemical forces and on the nature of both the lubricant and the metallic surface.

B. W. Hardy emphasized the highly complex nature of the phenomena of lubrication, especially the chemical problems connected with the mixing of substances of different lubricating powers.

J. E. Southcombe told of his experiments with the object of finding out in what respect the fatty oils differed from mineral oils. An abstract of his remarks will be given at a later date. (*Engineering*, vol. 108, no. 2814, December 5, 1919, pp. 758-760, 9)

MACHINE PARTS

Improved Worm Gear Having Efficiency of Over 97 Per Cent

DAVID BROWN & SON IMPROVED WORM GEAR. Description of a worm gear developed by a British concern. It is stated that in a certified test made at the National Physical Laboratory, Teddington, England, an efficiency of over 97 per cent was secured.

The illustrations (Fig. 2) show the details of the character and area of contact in the new F. J. gears. The view on the left shows the worm in such a position that the drive is taken by the three threads, A, B, and C, while that on the right shows the worm in a different position, having been rotated through an angle of 45 deg., with the result that the two threads A and B are in simultaneous contact with the worm wheel. The area in dotted outline across the teeth of the worm marks the zone of contact between the gears when the worm is rotated in the direction indicated in the end view. The intersections of the worm threads and the zone give the lines of contact between the worm and wheel teeth, and at no point outside this zone is there any contact between worm and wheel. It is this contour of the zone of contact that was arrived at by the mathematical calculation previously referred to, and which was submitted to Faraday House.

In the left-hand view, the actual contact between the worm

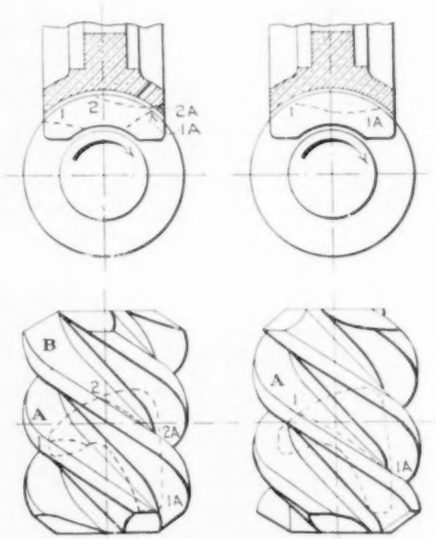


FIG. 2 ZONE OF CONTACT BETWEEN THE F. J. WORM AND WHEEL

thread A and the wheel is marked by the dotted line 1-1A, that between the worm thread B and the wheel by the line 2-2A, and on the worm thread C by the line 3-3A. In the right-hand view the worm has been rotated through an angle of 45 deg., the new line of contact being again shown dotted, only in this case the worm thread C has passed beyond the zone of contact and has thus ceased to make contact with the worm wheel.

The illustrations (Fig. 3) show the zone of contact for a four-threaded worm of the ordinary shape in which the teeth of the worm are straight-sided in section; that is to say, in the form of a rack. As the linear section of this type of worm corresponds to a straight-sided rack, and as the straight-sided rack forms the basis of the involute spur gear, this shape of worm is generally known as the involute worm. As before, the zone of contact is shown in dotted line, but in this instance two teeth only are in contact in the left-hand view—A and B—giving lines of contact 1-1A and 2-2A, while in the right-hand view the tooth A carries the entire load along the line of contact 1-1A. The unsymmetrical contour of the zone of contact will also be observed. More noticeable still is the difference between the irregular lines of contact shown on the end views of the involute worm as compared with the symmetrical lines of the F. J.

It must be understood that in both cases whenever the worm is revolved through an angle of 90 deg., the line of contact 1-1*A* will sweep across the zone of contact until it takes up the position marked 2-2*A*, because when a four-threaded worm is moved a quarter of a revolution (or 90 deg.), the thread *A* will naturally take up the position of the thread *B*. In the F. J. system it will be seen that the point 1 at the root of the worm (end view) falls into the position 2 after a quarter of a revolution; that is to say, the actual contact travels *in the same direction* as the worm through a distance of approximately 50 to 60 deg., hence about two-thirds of the motion is transmitted by a rolling action and only one-third by sliding. This means that a rolling action is introduced between the teeth of the gears, thereby reducing the ordinary rubbing velocity to a minimum. Thus the gear teeth, instead of rubbing against each other at, say, 1000 ft. per min., really only rub at the reduced speed of about 350 ft. per min., this being due wholly to the rolling action of the F. J. tooth contact.

This is not so on the involute worm-gear system. In the left-hand view in Fig. 2 the point of contact 1*A* actually moves *in the opposite direction* to the rotation of the worm to the point 2*A*, thereby giving the rubbing velocity even more than its full the-

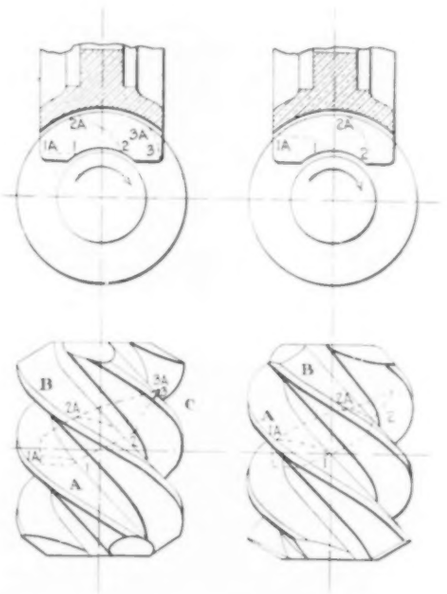


FIG. 3 ZONE OF CONTACT BETWEEN THE ORDINARY WORM AND WHEEL

oretical value, while rolling action, at the ends *A* of the lines of contact, is absolutely non-existent.

A peculiarly inefficient characteristic of the involute system is that the extremities of the lines of contact (see plan view of worm) travel from positions 1 and 1*A* *toward each other* until they meet, and vanish just beyond the points 2, 2*A*, as shown in the left-hand plan view (Fig. 3).

The plan view of the F. J. system (Fig. 2) shows the points *A* always moving from left to right, in the same direction as the rotation of the worm, while the left-hand plan view of the "involute" system shows the point *A* moving very slightly from right to left, actually against the rotation of the worm. The high rubbing velocity which occurs on the points *AA*, together with the converging lines of contact which induce a concentrated load, all tend to produce the worst possible conditions on the leaving side of the worm wheel. This explains the well-known fact that when a worm gear of the "involute" type is overloaded, "pitting" first takes place on this side of the wheel, and on this side only, while those portions of the teeth on the entering side of the wheel remain unmarked. (*The Automobile Engineer*, vol. 9, no. 133, December 1919, p. 449, 2 figs., *d*)

MACHINE SHOP

Tests on Best Speeds, Fits and Settings of Lathe Turning Tools

CUTTING POWER OF LATHE TURNING TOOLS, George W. Burley. In November 1913 Prof. W. Ripper and the present author read a paper under the same title as the present one before the Institution of Mechanical Engineers. The present article is a continuation of that article and deals with experiments made with lathe turning tools and in particular with such matters as relation between the cutting speed and the degree of finish obtained by the use of ordinary lathe finishing and light cutting tools and the influence of the various factors in tool design and position on the cutting power of the tools, power consumption, etc.

The paper, while of great interest, is too extensive for a detailed abstract. Because of this only the conclusions arrived at by the author are reproduced.

1 That there is no practical cutting speed below which it is impossible to obtain a satisfactory surface on plain-carbon steels by means of ordinary lathe finishing tools, whether these be made of plain carbon tool steel, ordinary (non-vanadium) high-speed steel, or superior (vanadium) high-speed steel. There is, however, a maximum limiting speed at or above which a satisfactory finish cannot be obtained on account of the tendency of the tool to pluck at and tear the surface, this tendency being related to the phenomenon of building up on the cutting edge of the tool. For the finishing of mild steel this limit is not very different from each of the above three varieties of tool steel and is within the range of 48 ft. to 58 ft. per min. For the finishing of hard steel this limit does depend somewhat on the variety of tool steel employed and is within the range of 23 ft. to 28 ft., 17 ft. to 21 ft., and 28 ft. to 34 ft. per min. for the three varieties, respectively.

2 The durability or life of a lathe finishing tool whether of plain carbon or high-speed steel, is for all cutting speeds below the limiting speed some function of the reciprocal of the cutting speed; in other words, an increase in the cutting speed below the limiting value is always accompanied by a decrease in the life or durability of the tool.

3 The most suitable angle of side rake (that is, the angle of side rake associated with maximum durability and cutting power) for a high-speed lathe roughing tool working on steel depends upon the physical properties of the steel. For mild-steel turning it lies between 20 and 25 deg., while for hard-steel turning it is of the order of 10 deg.; and if these angles are either increased or reduced there is always a depreciation of cutting power.

4 The color of the turnings formed by a high-speed lathe roughing tool when working on steel is not necessarily a true index of the condition of maximum cutting efficiency. Thus, in the case of hard-steel turning, the turning color which is associated with maximum cutting efficiency is a pale blue, while a mild-steel turning which is removed under the conditions of maximum efficiency is practically uncolored, apart, of course, from the natural gray color of the steel.

5 The net power consumption of a high-speed roughing tool is dependent, other conditions being constant, upon the amount of top rake on the tool, the relation between these two quantities being reciprocal in character, so that, within the limits of ordinary practice, a reduction in the top-rake angles of a tool is always accompanied by an increase in the net amount of power consumed. The law connecting the variations of the two quantities appears to be of the nature of a straight-line law for all qualities of steel machined. There are, therefore, no critical values of the rake angles in regard to power consumption as there are in regard to durability and cutting power.

6 The cutting power of a high-speed lathe tool is influenced by both the cross-sectional area of the shank of the tool and the nose radius, but the influence of the latter factor very largely predominates in all cases. Thus with a number of different sections of tool steel, an increase of the nose radius of 100 per cent produced an average increase in the cutting power of 45 per cent; whereas an increase of the cross-section of the shank of the tool of 500 per cent with a constant nose radius produced an average increase in the cutting power of only 8.5 per cent.

7 The effect of raising a roughing tool so that its cutting edge is slightly above the horizontal plane passing through the lathe centers is, generally, to increase the cutting power of the tool slightly and to reduce its net power consumption slightly, when compared with its normal position, that is, with its cutting edge at the same height as the lathe-center axis.

8 Forging the nose of a lathe cutting tool does not materially affect its cutting power and durability, there being practically nothing to choose between a completely ground tool and a forged and ground tool, otherwise identical.

9 The general direction and the active length of the cutting edge of a high-speed tool have a slight influence upon the net power consumption of the tool, the influence being such that, with any given depth of cut, if the active length of the cutting edge is increased by an alteration of the general direction of the edge, the net power consumed is increased under conditions of working otherwise identical.

10 There is no marked difference in the net amounts of energy required per cubic inch of material removed from mild-steel and hard-steel bars at high and low cutting speeds.

11 The increase in the cutting power of a high-speed roughing tool resulting from the use of a given stream of water as a cooling agent is greater with small cuts than with heavier ones, indicating that, with heavier cuts, heavier flows of coolant should be used. The velocity of flow of a stream of coolant does not very materially affect the improvement in the cutting power of a tool due to the use of the coolant, provided that the velocity is not such as to cause excessive splashing of the coolant.

12 The cutting efficiency of a high-speed roughing tool depends very largely upon the condition of the cutting edge of the tool, and though a tool with its cutting edge blunted in the cutting process may continue to cut, it cannot be used in that condition for the purpose of starting a new cut. (Paper before the Institution of Mechanical Engineers, Dec. 19, 1919, *Journal of the Institution of Mechanical Engineers*. Compare also *Engineering*, vol. 108, no. 2817, Dec. 26, 1919, pp. 867-875, 91 figs., *eA*)

opening, as indicated at *C*, Fig. 4. This opening is made by means of a diamond chip held by hand between the points of a pair of long-nosed pliers. After the conical hole has been cut, the drilling operation is started by means of a tool carried in the spindle of the machine, which is so designed that the table rotates and also has a vertical reciprocating motion imparted to it.

After the hole has been drilled about three-quarters of the way through the diamond, as indicated at *D*, the work is removed from the machine and turned over, after which it is reset and the conical opening is cut in the opposite side of the diamond, as indicated at *E*. Of course, this second conical opening has to be located exactly opposite the hole which has been drilled in the work. The next step is to drill from the bottom of this conical opening to make a connection with the hole entering the stone from the opposite side, *F*. It is very important to have the inside of the die absolutely smooth in order to prevent forming seams in the work and also to have the bell mouth of the die formed in such a way that the metal will pass into the die without undue frictional resistance. This is done by giving the die the shape shown at *G*. The inlet to the throat of the die is made slightly larger than the outlet at the back, which requires a great amount of dexterity to do. The dies are set in brass mounts.

The feature of diamond dies which makes them more economical in use than steel, cast iron or other comparatively inexpensive materials, is that they give a far greater amount of service before the tool is worn out, because of the extreme hardness of the diamond. This resistance against wear is also the means of maintaining greater uniformity in the diameter of the wire that is drawn through the die.

The time comes, however, when the die becomes too large to produce wire that comes within the specified limit of tolerance. When this point has been reached the die is recut for a larger size, which is done by the use of a steel lapping tool charged with diamond dust. In connection with this operation the bell-mouthed opening must again be carefully finished to bring it tangent to the new throat which has been cut in the die and the inner surface must once more be carefully polished. The original article illustrates the special type of lathe used for refinishing diamond dies. (*Machinery*, vol. 26, no. 3, Nov. 1919, pp. 264-266, 5 figs., *d*)

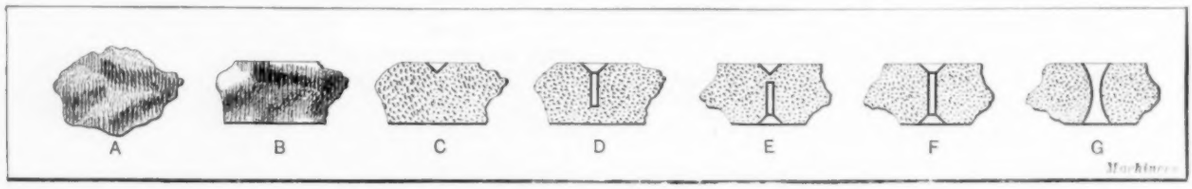


FIG. 4 ROUGH DIAMOND (A) AND THE CROSS-SECTIONAL VIEWS SHOWING SUCCESSIVE STEPS IN THE PROCESS OF MAKING WIRE-DRAWING DIES

MECHANICAL PROCESSES

Diamond Dies and How They Are Made

MAKING DIAMOND WIRE-DRAWING DIES, Edward K. Hammond. Diamond dies are extensively used for drawing small wire made of all kinds of metals and for sizes from 0.08 in. down they are used practically exclusively. Because of this the following data as to the manufacture of such dies by the Vianney Wire Die Works at Trevoux, France, become of interest.

For the manufacture of dies diamonds are used which are of a grade unsuitable for use in jewelry.

The firm standardized the size of diamonds from which dies of different diameters are made, the diamonds themselves ranging from one carat to sizes as large as twenty carats.

As is generally known, the diamond is so hard that it can be cut only with another diamond or diamond dust. The first step is the flattening of a rough stone, which is done with laps charged with diamond dust made by pulverizing small-sized diamonds or chips from larger stones and then grading the dust by sifting it through sieves with various numbers of meshes per square inch. This is succeeded by several operations, comprising the cutting of the die opening. The first step is to chuck the diamond on the faceplate of a special drilling machine and cut a conical-shaped

MECHANICS

French Tests on Longitudinal Internal Stresses in Rapidly Cooled Steel Cylinders

INFLUENCE OF VARIOUS FACTORS ON THE RISE OF LONGITUDINAL INTERNAL STRESSES DUE TO RAPID COOLING OF STEEL CYLINDERS, M. Portevin. The longitudinal internal stresses were determined by measuring by means of a comparator the change of length which accompanied the removal in a lathe of concentric layers of metal on the cylinder.

The necessity of keeping the test pieces in a state of easy machining limited the initial temperatures of rapid cooling to the lower point of transformation of steel, which is around 700 deg. cent. (1292 deg. fahr.) in order to avoid the hardening which would follow other treatment.

The internal stresses were computed by using the formula of Heyn and Bauer. If l and l_n are the initial length of a test and its length up to the removal of the nth layer, S''_n the area of a straight section remaining after the removal of the nth layer, and

E the modulus of elasticity of the metal, then the stress f_n which was initially present in the nth layer is

$$f_n = \frac{E}{l} \frac{S''_n(l_n - l) - S''_{n-1}(l_{n-1} - l)}{S''_{n-1} - S''_n}$$

For a given steel the internal stresses produced by rapid cooling are a consequence of the lack of isothermic condition of the mass, that is, of instantaneous inequality of distribution of temperatures during this operation. These variations of temperature at various points of a metal cylinder cooled by immersion into a liquid vary with the temperature of immersion, the external conditions of cooling and the diameter of the cylinder. In particular, the external conditions of cooling depend on the nature of the cooling liquid, its temperature and the duration of the immersion.

In the present instance the author investigates in a quantitative manner the results obtained by varying separately these different factors. The numerical results of the same investigation will be published separately.

Temperature of Immersion. The internal stresses rise very rapidly with the temperature of immersion when this latter increases from 200 deg. cent. (392 deg. fahr.) to 600 deg. cent. (1112 deg. fahr.) They are practically nil for temperatures below 200 deg. cent. (392 deg. fahr.) and the diagram of Fig. 5 gives for a steel cylinder the curves of internal stresses as a function of the square of the distance from the axis.

For reasons given above (necessity of keeping the metal machinable) the tests were not carried to higher temperatures, but in view of the viscosity of steel at high temperatures no material increase of internal stresses was to be expected.

Nature of the Cooling Liquid. Comparison of internal stresses arising through immersion in water and in oil at a temperature of 650 deg. cent. (1202 deg. fahr.) shows that in the latter case they are from two to four times smaller than in the former, according to the character of the steel and according to whether we consider the peripheral stresses of compression or the axial stresses of expansion.

Temperature of the Water. The internal stresses decrease with the temperature of the water and become practically nil for a temperature of 100 deg. cent. (212 deg. fahr.). The curves of Fig. 6 indicate this variation for a hard steel. It is found that when the temperature of the water is increased by 12 to 25 deg. cent. (21.6 to 45 deg. fahr.) a reduction of internal stresses is observed, small but unnoticeable, and in addition the internal stresses lose a good deal of their regularity, that is, they cease to maintain materially the character of revolution around the axis of the cylinder.

Duration of Immersion. In tests where the duration of immersion was, respectively, 1.5, 3.5, 8 and 13 sec., there was a net increase in the internal stresses for the case of cylinders immersed in the water at a temperature of 650 deg. cent. (1202 deg. fahr.). This is also apparent for the range of temperatures between 8 sec. and 13 sec., although by interpolating results of previous tests it may be estimated that beginning with 5 sec. the axial temperature falls below 300 deg. cent. (572 deg. fahr.). Fig. 7 gives the internal stresses as a function of the square of the distance from the axis for a semi-hard steel cylinder.

Diameter of the Cylinder. Tests carried out on semi-hard steel cylinders of 20 mm., 35 mm., 50 mm. and 60 mm. (0.7 in., 1.37 in., 1.96 in., 2.36 in.) in diameter, respectively, have given results in which the anomalies are apparently due to experimental errors, but which nevertheless indicate the decrease of internal stresses with the diameter, a decrease, it may be remarked, which is really not very rapid.

A knowledge of these results was necessary for clearing up the entire problem of tempering of steel. (Etude de l'influence de divers facteurs sur la création des efforts internes longitudinaux lors du refroidissement rapide de cylindres d'acier. *Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences*, vol. 169, no. 21, Nov. 24, 1919, pp. 955-957, 3 figs., *e.l.*)

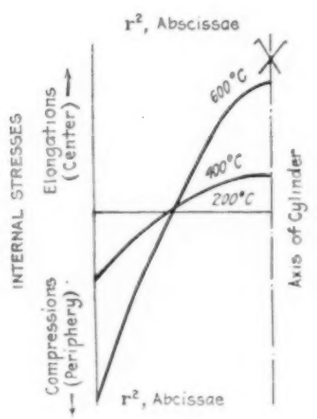


Fig. 5

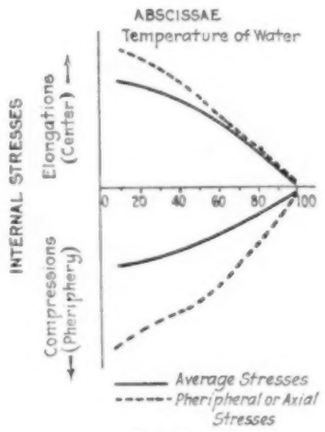


Fig. 6

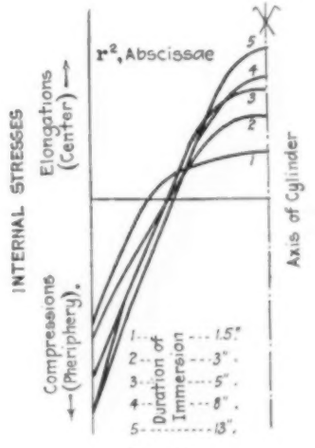


Fig. 7

Fig. 5 Variation of Internal Stresses in Rapidly Cooled Steel Cylinders as a Function of the Temperature of Immersion. Fig. 6 Variation of Internal Stresses in Rapidly Cooled Steel Cylinders as a Function of the Temperature of the Water. Fig. 7 Variation of Internal Stresses in Rapidly Cooled Steel Cylinders as a Function of the Duration of Immersion

METALLURGY

Description of Modern Methods of Making Puddled Iron

Puddled-Iron Practice, J. E. Fletcher. There has been a material revival of interest in puddling iron. Hall's process lies at the root of present and future puddling processes and is not likely to be superseded. It is conceivable that further attempts may be made to produce wrought iron directly from poorly silicious ores or by the decarburization of cheaply produced mild steel, but there are fundamental difficulties in the way of success affecting the character of the crystalline structure and the related welding and fibering properties of the resulting product.

There are three factors in puddling that affect the entire situation. These factors are:

1 The puddling furnace as we now know it is one of the most wasteful of metallurgical furnaces, using more fuel per ton of product than any other continuous process.

2 The labor cost per ton is abnormally high as is also the cost of furnace upkeep.

3 The rolling, shingling and material handling and transport plants are usually crude and excessively wasteful in power cost per ton of product.

The writer vigorously criticises the design of coal-fired puddling furnaces, claiming that the radiation losses in such a furnace and its waste-heat boiler amount to at least 20 per cent of the heat

energy of the coal burned or equivalent to, say, 560 to 784 lb. per ton of puddled-iron heat, whereas in the steel furnace the radiation losses do not exceed 224 lb. per ton of steel cast.

The radiation losses in a puddling furnace per unit of metal charged average from 10 to 15 times as much as in the open-hearth steel furnace, and so on.

On the whole, the author comes to the conclusion that the small furnace used in puddling is a real obstacle to fuel economy as its relatively large hearth causes the excessive radiation areas.

The construction and proportions of the modern puddling furnace are not likely to be substantially altered or improved, but it is possible, to improve the grate and firebox and to provide

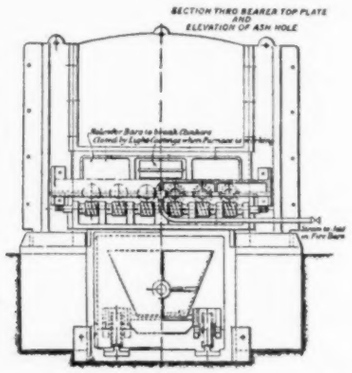


FIG. 8 END ELEVATION OF FURNACE ARRANGED FOR EASY REMOVAL OF ASHES

efficient means for burning the poorer coals—in particular, to reduce the amount of unburned fuel that goes into the ashpit. Figs. 8 and 9 show sections of a furnace arrangement designed by the author.

The grate consists of a series of tubular bars perforated for air ejection, over which a number of specially shaped chilled cast-

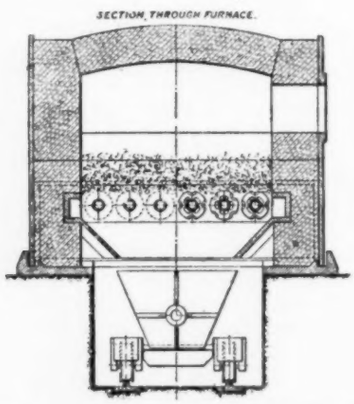


FIG. 9 SECTION THROUGH FURNACE SHOWING ARRANGEMENT OF GRATES

iron disks are threaded. These form a kind of roller grooved longitudinally, so that when it is rotated it causes clinkers to crack and burned ashes accumulated in the troughs betwen the roller bars to roll into the ashpit.

The air required for combustion is forced through the tubes by steam jets and passes out through the perforations into the fuel bed and ashpit which is closed by the front plate of the ash-removal car. The air ducts between the grate disks are nozzle-shaped and the grates can be cleaned without opening the doors. Large clinkers can be removed through the large holes provided above the grate in the firebox back plate.

The application of gas firing to small puddling furnaces has also been suggested and a furnace was built with a small producer at the firing end.

The process of puddling covers three stages, namely, the melting stage, occupying 30 to 40 min. depending on the class of pig iron used and the efficiency of the fuel; the boiling stage, occupying 30 min.; and the drying and balling, followed by fettling and charging periods, occupying about 40 min.

It appears further that the melting period demands, under the present conditions, from a little over 5000 lb. to close to 6000 lb. of coal per ton of metal melted and is the most wasteful stage of the puddling process.

Cupola melting which would be more economical as far as fuel consumption goes is not suitable as it yields a higher-carbon metal and very little reduction of the remaining metalloids, and because of this the boiling period in the puddling furnace is lengthened.

The author proposes a special method of procedure based on manipulation of the slags with a view to producing a low-sulphur metal from the cupola described in the original article.

The characteristic feature of the new process is the addition of manganese at a certain stage which causes a delay in the elimination of the carbon, while it accelerates the elimination of silicon and phosphorus. A liquid slag resulted and the metal poured flows easily and is well deoxidized.

The author also proposes the design of a plant consisting of an open-hearth tilting or fixed basin-lined furnace, the waste heat from which is used in attached efficient boilers fitted with auxiliary fuel-supply apparatus, this latter having the purpose of increasing the steam requirements during the charging and tapping stages. From the open-hearth roughing furnace the metal is ladled to mechanical puddling furnaces fired with pulverized coal and having waste-heat boilers attached to them.

Each of the units composing the proposed plant are at work. The open hearth furnace is regularly melting iron on a pulverized-coal consumption of 448 to 560 lb. per ton of iron melted. Puddling furnaces similarly fired are operating on a consumption of 1300 to 1600 lb. per ton of puddled bar, when dealing with cold pig iron. When puddling molten charged material the coal burned should not exceed 800 to 1000 lb. per ton of product, six furnaces doing the work of the present ten.

If the roll trains and shingling machines or squeezers be operated by electrical power, and they can be, it is conceivable, that, given cheap electrical energy, such a combination of the duplex system with mechanical puddling furnaces and with electrical rolling and shingling equipment should furnish the most economical puddling plant possible. (Paper before the Staffordshire Iron and Steel Institute read Nov. 22, 1919, abstracted through *The Iron Trade Review*, vol. 66, no. 2, Jan. 8, 1920, pp. 152-156, 4 figs. *dg*)

PHYSICS

ABSOLUTE UNIT OF TIME BASED ON NEWTONIAN LAWS, Gabriel Lippmann. The unit of time in general use, namely, the second, is an arbitrary and not an absolute unit. It is a submultiple of the solar day and can be obtained only by astronomic observation. If some fabulous being flew over from the solar system to Sirius, he would have lost the second on the way, at the instant when the earth's system disappeared from his sight. On the other hand, if the same being had some formula to express an absolute unit of time, he could reconstruct this unit no matter in what part of the world's system he might happen to be. In physics the use of the absolute unit is, however, of quite a practical value in that it permits the elimination of arbitrary numerical coefficients. Such coefficients are inconvenient in that they complicate the form of equations, introduce a possible source of error, and, what is still more important, in numerical computations tend to conceal the nature of relations existing between phenomena of different character. Without absolute units it would have been very difficult to create the electromagnetic theory of light, for example. It is therefore very desirable to secure a definition of a unit of time in absolute measurements.

The present author builds up an absolute unit of time on the

basis of the Newtonian theory of gravitation. In accordance with this theory

$$f = k\frac{mm'}{r^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where f is the static force of attraction between masses m and m' at a distance r from each other, and k is the Newtonian coefficient of attraction, the numerical value of which depends on the units of measurement selected, which may be such that $k = 1$. By this the unit of force is determined: It is the attraction which exists between two masses, each of which is equal to unity, separated by a unit of distance.

Hence, if we call γ the intensity of the Newtonian field due to a mass m at a distance r, we have $f = \gamma m'$, and hence

$$\gamma = \frac{m}{r^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots [3]$$

Hitherto only static forces were considered and the element of time was absent.

But let us consider now the acceleration given to mass m by the force f, assuming that the force is equal to the product of mass by acceleration. We have then

$$\frac{m}{r^2} = \frac{d^2r}{d\theta^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots [4]$$

where the value of the second member depends on the unit of time employed; conversely, Equation [4] defines the unit of force employed as the first member of the equation is completely defined. We may therefore write

$$\gamma = \frac{d^2r}{d\theta^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots [5]$$

The unit of force is therefore such that the acceleration is numerically equal to the intensity of weight, or the acceleration is equal to unity in a gravitational field equal to unity.

We may now calculate the dimensions of the absolute time We have to admit in the usual manner that the mass is measured by the product of a volume L^3 by density φ, this latter being taken for a substance of such type of water. Equation [4] becomes then

$$\frac{\varphi L^3}{L^2} = \frac{L}{\Theta^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots [6]$$

Hence

$$\Theta = \frac{1}{\sqrt{\varphi}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [7]$$

The absolute time is therefore a zero dimension in reference to lengths, which means that a unit of time is independent of the choice of units of length and is the same in the centimeter-gram system or the meter-ton system, or even the foot-cubic-foot system. As regards the coefficient φ, it has to be considered only if we wish to attempt to replace water as a typical substance by some other substance. For example, if we should desire to replace by mercury, the factor $\sqrt{\varphi}$ would be equal to $\sqrt{13.6}$ and the unit of time would be $\sqrt{13.6}$ times greater.

The author discusses in detail the methods of introducing this absolute unit of time into various physical computations. (*Annales de Physique*, 9th series, vol. 12, Sept.-Oct., 1919, pp. 226-237, *t*)

RAILROAD ENGINEERING

RIPKEN AUTOMATIC DRIFTING VALVE FOR LOCOMOTIVES. Description of a drifting valve which is operated by the compression in the cylinder, known as the Ripken valve, and in use on the Minneapolis, St. Paul and Sault Sainte Marie Railroad.

The valve comes into operation before the cylinders are emptied of steam pressure after the throttle has been closed and is kept in operation and furnishes the needed amount of steam until the pistons cease to move. It is automatically closed just as the engine stops by the building up of pressure in the steam chest.

Only one valve per engine is used as the steam is passed directly to the branch pipe or the saturated end of the superheater header. This arrangement is advantageous as it reduces the amount of steam required and also protects the superheater elements against overheating. It makes unnecessary the use of either air relief valves or bypass valves.

The original article illustrates and describes the construction of the valve, which is, however, well known generally. It also gives a series of indicator cards from an engine fitted with the Ripken valve, shown in Fig. 10.

Tests on a superheater locomotive with 25-in. by 26-in. cylinders supplied with steam from a 2-in. pipe showed that the valve when adjusted between 25 and 30 lb. pressure in the steam chest at 25 per cent cut-off at a speed of 60 miles an hour, prevented the formation of harmful vacuum even at such high speed. After a shut-off with the reverse lever in running position, the valve would open when the steam-chest pressure rose to 49 lb., which

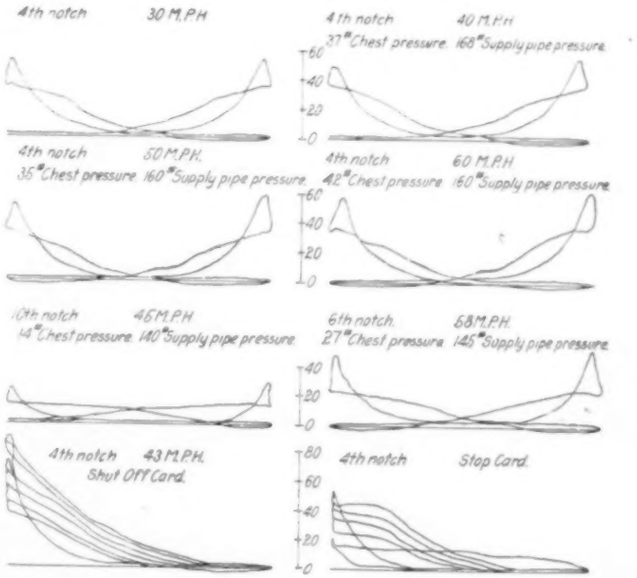


FIG. 10 TYPICAL INDICATOR CARDS FROM A LOCOMOTIVE ENGINE FITTED WITH THE RIPKEN AUTOMATIC DRIFTING VALVE

occurred just before the stop, allowing time for the superheater to empty itself before the engine came to rest. (*Railway Age*, vol. 67, no. 22, Nov. 28, 1919, pp. 1079-1080, 2 figs., *de*)

USE AND HANDLING OF FUEL OIL, A. M. Schoen. Paper presented before the Railway Fire Protection Association Convention at Chicago in November 1919, at the same time as the Report of the Committee on Oil-Burning Appliances, B. S. Mace, Chairman.

The Report of the Committee contains specific rules and requirements for the storage and use of fuel oil and for the construction and installation of oil-burning equipment.

A. M. Schoen's paper called attention to the fact that while oil has been used for locomotives in the West and on the Florida East Coast for a number of years, there would appear to be no well-defined standards accepted, and even the individual railroads appear to consider this fuel as not yet entirely permanent. It seems, however, to be time to formulate standard specifications in an advisory form, at least, that may be adopted by railroads preparing to adopt oil as fuel.

Not enough attention is being paid to safeguarding the storage of oil at points along the right of way, the loading and unloading of the oil, and the fueling of the tenders.

One of the obstacles to the determination of uniform standards lies in the wide variation in the flash test and viscosity test of the oils employed for fuel purposes in the different parts of the country.

A number of recommendations are made as to the design and location of large storage tanks and methods of fueling of tenders. (*Railway Age*, vol. 67, no. 22, Nov. 28, 1919, pp. 1069-1071, *gp*)

REFRIGERATION

Salt Precipitation from Mixed Solutions by Crystallization through Refrigeration

SALT PRECIPITATION BY REFRIGERATION, Berthold Block. In the chemical industry many salts have to be precipitated out of mixed solutions by means of crystallization. This is done by cooling the concentrated brines to the point where their ability to maintain the salts in solution is reduced.

Fig. 11 gives the solution curves of several salts in water, indicating how much of the salt at various temperatures may be contained in 100 grams of water (saturated solutions). As shown by these curves, the solubilities of various salts are unlike to an extraordinary degree and each salt will yield a greater or lesser precipitation out of a brine at a given temperature.

Thus, for example, in the case of Chilean saltpeter ($NaNO_3$) cooled from 90 to 20 deg. cent. (194 to 68 deg. fahr.), out of 165 grams held in solution at 90 deg. cent. so much is precipitated out that only 88 grams remain in solution.

The curves show that many brines can maintain quite considerable amounts of salt in solution even at 20 deg. cent. (68 deg. fahr.) and that substantial amounts of crystals are precipitated only when the brine is cooled to a considerably lower temperature.

Because of this, provision has to be made for certain salts to cool the brine to quite a low temperature and Fig. 12, for example, shows an installation built to precipitate out of its solution potassium chloride. In this case 3000 grams of brine at 20 deg. when cooled to — 10 deg. (14 deg. fahr.) will precipitate out in crystal form 200 grams of potassium chloride.

The cooling is effected in two stages: by means of a water cooler to + 20 deg. cent. (68 deg. fahr.), and then in an ammonia refrigerating machine to — 10 deg. cent. (14 deg. fahr.).

The ammonia compressor *A* compresses the ammonia and forces it into a coil condenser *B*, in which ammonia under a pressure of 8 atmos. is liquefied by cooling water having a temperature of 15 deg. cent. (59 deg. fahr.). The liquid ammonia, the flow of which is controlled by a special valve, is then again vaporized in the coils *C* of the crystallizing cooler *D*, the ammonia then going back to the compressor by means of pipe *E*.

The precipitation of the crystals is produced by cooling the brine in cooler *B*, the salt settling mainly on the cooling coils *C*. It is then swept off of them by special adjustable brushes, which also help to maintain the efficiency of the cooling action of the coil *C*. The crystals precipitated in this way sink through the brine and collect in the cone-shaped bottom of the cooler, whence they are from time to time discharged into the straining tank *O* through a quick-acting valve *G*. It is necessary to have the valve of a quick-acting type in order to have the liquid pressure discharge the crystals containing brine without letting out too much liquid itself. The straining tank *O* has on top a fine screen on which the brine falls. The thin liquid passes through and is strained off while the crystals remain on top of the screen and are collected therefrom from time to time.

In the installation described approximately 6000 calories (say, 24,000 B.t.u.) would have to be absorbed from the refrigerating plant per hour. In order to reduce the consumption of cold the installation is so arranged that the brine which leaves the crystallizing cooler *D* at *H* is conducted to the jacket of a second crystallizing cooler *J* and on the way precools the fresh brine which enters at *K* with the temperature of 20 deg. cent. (68 deg. fahr.).

Brine entering with the temperature of — 10 deg. cent. (14 deg. fahr.) takes up heat to the extent of leaving the cooler *J* with the temperature of 5 deg. cent. (41 deg. fahr.), whereas the fresh brine which enters with the temperature of 20 deg. cent. (68 deg. fahr.) leaves with the temperature of 5 deg. cent. (41 deg. fahr.). The salt which is crystallized out in the meantime is swept away by brushes in the same manner as in the first cooler and precipitates out through the quick-acting valve *L* into the same straining tank *O*. In this manner the consumption of cold is reduced to about one-half.

In computing the consumption of heat in refrigerating installations of this type it is necessary to bear in mind that in addition to the heat which is necessary to cool the brine itself, quite considerable amounts of heat have to be taken care of as heat is given up in the process of precipitation by crystallization at the instant

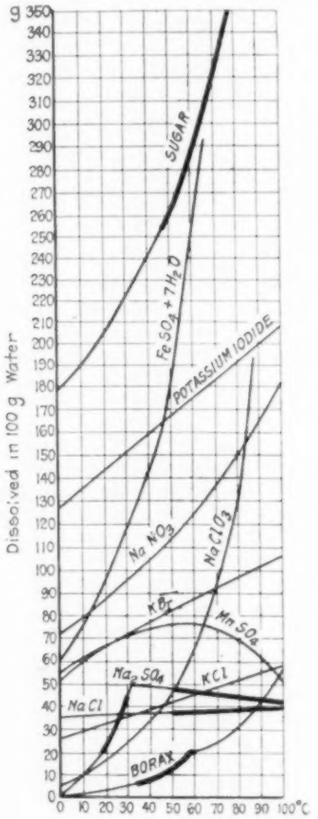


FIG. 11 SOLUBILITY CURVES OF VARIOUS SALTS

when the dissolved salt passes into the form of crystals, the amount of heat thus given up being the same as that which was previously consumed in order to dissolve the salt. In the case of cooking salt about 20 calories per kilogram (35 B.t.u. per lb.)

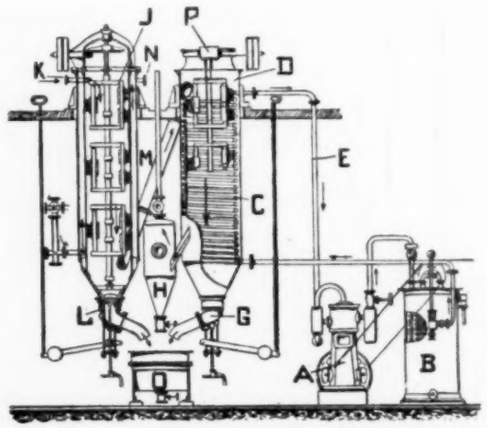


FIG. 12 EMIL PASSBURG INSTALLATION FOR PRECIPITATION OF SALTS OUT OF SOLUTIONS BY REFRIGERATION

were consumed, for potassium chloride ($KClO_3$) about 81.5 calories per kilogram (147 B.t.u. per lb.) and so on. (*Zeitschrift für die Gesamte Kälte-Industrie*, vol. 26, no. 8, August 1919, pp. 57-59, 3 figs., *d*)

STEAM ENGINEERING (See also Railroad Engineering)

EMPLOYMENT OF NOZZLES INSTEAD OF CYLINDERS OR WHEELS IN TURBINES, Prof. R. Mollier. In 1904 Professor Dolder proposed in the *Schweizerische Bauzeitung* a new idea for the improvement of steam turbines, the main feature of which consisted in removing in the turbine only so much of the available energy of the steam jet that the steam might be able to regain its initial pressure in an expanded nozzle.

By these methods it was believed to be possible to shift the cycle at will into a range of high efficiency. The velocity in the turbine could be made as small as desirable and the compressor, which otherwise would be necessary with such a cycle, could be left out.

Professor Stodola denied the possibility of practically applying such a scheme. He pointed out the injurious effects of the resistances which would occur in all parts of the cycle, and brought forward as a deciding argument against the feasibility of such a cycle, the fact that the condensing steam always settles on the walls, which means loss of its kinetic energy.

The author states, however, that he himself was recently considering the same scheme in various forms; among others, its application in a reversed cycle to refrigerating machines, which he thought might be possible since with air or other non-condensable gases the fundamental objection brought forward by Stodola would not have to be considered. The scheme itself seemed to be highly attractive and if it could have been carried out in practice would have been of great benefit.

A closer investigation showed, however, that the presence of excessive resistance, which was only barely indicated by Stodola, offered an insuperable objection to the carrying out of this scheme.

It is the custom to carry out all kinds of changes of state of gases, in particular cyclic changes, in one or more cylinders with movable pistons and predetermined addition or abstraction of heat. There is, however, another way to do it and that is by substituting for the cylinder with movable piston a duct with variable cross-section through which the flow of gas takes place. If we neglect the question of frictional resistance the addition and absorption of heat will be the same as in the case of a cylinder with a movable piston.

In a cycle of the character occurring in the case of a duct of variable cross-section, there will be instead of work directed on to the piston a variation of kinetic energy of the gas. Should the cycle be continuous, we would then have to construct a circular duct, and the excess of energy created by the process would have to be abstracted from the gas at some point of the cycle, for example, by means of a turbine; or, if the cycle is of such a character that the kinetic energy of the gases is reduced, then at some place in the cycle this loss of energy would have to be made good by some means, for example, by a turbo-compressor. In both processes, however, the rule holds good that on the whole the amount of work either gained or expended by the gas is equal to the amount of heat that is either abstracted from or delivered to the same gas.

In cycles of the first class, that is, cylinders with movable pistons, the velocities of the gas are so small that the work necessary to overcome the resistance thus produced may be neglected entirely, and in a cycle of this character the integrals

$$\int pdv = -\int vdp \text{ and } \int Tds = -\int sdT$$

may be taken as fully representing the work gained during the cycle or the work expended to carry it out. In these equations p, v, T and s represent respectively the pressure, volume, absolute temperature and entropy of the gases.

In the cycle of the second class, that is, a duct with variable cross-section, the resistance cannot be neglected since in that case we are dealing with great, and often very great, velocities.

In a cycle of that character the work gained or lost cannot be expressed by the above integrals and the area of the cycle cannot be expressed in the p-v or T-s diagrams. As a matter of fact it is greater or less than that expressed by the above integrals, by the amount of the work of resistance W, so that the variation of energy is in that case expressed by

$$E = -\int vdp - W$$

Because of this, it appears that if in a heat engine the friction is equal to the integral of the area of work, the whole work produced by the engine disappears and the engine fails to work. The amount of heat introduced from outside is entirely consumed but at the same time a certain amount of heat passes from the hot body (working chamber of the engine) to the cold body (cooling jacket, however expressed).

The author considers in detail the amounts of resistances which are met with in the cycle proposed by Professor Dolder, whether it be for the case of a steam turbine or an air refrigerating machine, and shows that the resistances are so great as to make the ultimate efficiency of the cycle extremely low. (Ueber die Anwendung von Düsen an Stelle von Zylindern oder Kreiselrädern, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 63, no. 35, August 30, 1919, pp. 830-833, 6 figs., *t*)

DEFLECTION OF STAYBOLTS IN LOCOMOTIVE BOILERS, Geo. L. Fowler, Mem.Am.Soc.M.E. As the length of fireboxes increased there was an increase in staybolt breakages and while there were many theories as to the cause of it, the amount of experimental data was quite limited.

In the present investigation an attempt was made to determine by actual measurement the amount of relative movement between the inner and the outer sheets of a locomotive firebox and also when the motion occurred and what was its general character.

The apparatus used was designed to resolve the motion of the inner sheet relatively to the outer one into its vertical and horizontal components and project them on a screen. These were afterward recombined to plot this relative movement in the form of a diagram.

The investigation is so extensive that only some of its conclusions can be reported here. The fundamental facts brought out were that the staybolt deflection is much greater in a flexibly stayed boiler than in a rigidly stayed boiler. It appears also that during the whole period of operation and probably until the boiler temperature has reached that of the atmosphere, the staybolt is in constant motion. The two types of boiler construction (Wootten and radially stayed) have quite different effects on staybolt deflection and firebox temperatures, and the action of the tubes has a marked influence on staybolt deflection at the front end of the firebox.

The tests also showed the great sensitiveness of the plates to changes of temperature. For example, a cold boiler may be filled with water of any temperature from cold to boiling and there will be no relative motion between the sheets. But let the fire be laid and a piece of lighted waste thrown in to ignite it, and it has, thus far, been impossible to get a reading before the sheets would show a movement, though this has been done within 10 sec. from the time of ignition of the waste.

The general impression left by the tests is that the Wootten firebox is much more rigid than the wide firebox when rigidly stayed with radial stays, and the difference might be still greater if it were given a complete installation of flexible bolts.

Because of the great sensitiveness of the sheets to changes of firebox temperature, it would appear that a boiler which is so built as to permit the sheets to expand under the influence of temperature changes will put less stress upon the staybolts and sheets than one where such motion does not exist.

The tests apparently left the observers with the conviction that the flexible bolt has superior possibilities as a means of reducing the probable stresses that the several parts of the boiler are called upon to sustain. (*Railway Age*, vol. 67, no. 23, December 5, 1919, pp. 1088-1094, 13 figs., *eA*)

TESTING AND MEASUREMENTS

TESTING ABRASIVE WHEELS FOR EFFICIENCY, Raymond Francis Yates. Description of methods for testing abrasive wheels and some of the results obtained.

There are cases where it is necessary to determine the efficiency of various types and makes of abrasive wheels. In particular, the manufacturer of such wheels must have methods to determine which of his products gives the best efficiency.

Wheels are made in various grits, grades and bonds. By grit is meant the size of the abrasive particles that constitute the wheel, the particles being graded by the number of meshes to the square inch on a screen through which they pass. Thus, 10 would represent a very coarse wheel, while 200 would indicate a wheel composed of fine particles. Grade indicates the nature of the abrasive substance as regards its temper or hardness, and electrothermically it is now possible to produce abrasive substances of desired hardness. The bond of a wheel is the substance that holds the abrasive particles together in a solid form. It is extremely important and is a large factor in the determination of the efficiency of the wheel when cutting certain substances. For instance, if a wheel is cutting cast iron and its bond is not of the proper nature the particles may lose their sharpness and yet remain in place, or the bond may not be able to hold until they become sufficiently dull to break away from the rest of the wheel. In the first place very low cutting efficiency will result, as the dull abrasive particles hang on to the wheel and cause undue friction in rubbing over the surface of the iron. In the second case the wheel may cut freely and quickly, but will wear down very rapidly. (*American Machinist*, vol. 52, no. 3, Jan. 15, 1920, pp. 139-141, 6 figs., *ep*)

THERMODYNAMICS

SPECIFIC HEAT OF AIR AT ROOM TEMPERATURE AND AT LOW TEMPERATURES, Karl Scheel and Wilhelm Heuse. An extensive paper of which only the conclusions can be given here on account of limited space available.

The specific heats of air were determined by means of two calorimeters and the average data of observations are presented in Table 2, where, in addition to the direct readings, are given the corresponding units in calorie masses obtained from electric mass by multiplying the latter with the heat equivalent of the watt-second, which is

$$0.23865 \frac{\text{g-cal}_{20}}{\text{watt-sec.}}$$

The tests confirm what has already been found by Swann, namely, that the specific heat of air at room temperature is considerably greater than that found by previous investigators, in particular by Regnault.

The value given by Swann in caloric mass units, namely,

$$0.24173 \frac{\text{g-cal.}_{20}}{\text{g-deg.}}$$

was based on the value of 20-deg. calorie = 4.180 watt-seconds. From this may be computed the comparable value of the specific heat of air at 20 deg. in electric mass units

$$1.010 \frac{\text{watt-sec.}}{\text{g-deg.}}$$

which agrees perfectly with the results obtained by the present writers.

The value of the specific heat permits us also to determine the relation between the specific heats of air in accordance with the formula $c_p/c_v = x$. Usually

$$c_p - c_v = T \left(\frac{dp}{dT}\right)_v \times \left(\frac{dv}{dT}\right)_p$$

If one wishes to determine the values on the right-hand side of the equation, the van der Waals equation of state, then for atmospheric pressure and room temperature one obtains

$$c_p - c_v = \frac{R}{M} \times 1.0045 \frac{\text{watt-sec}}{\text{g-deg.}}$$

where $R = 8.316$, which is the gas constant, and $M = 28.95$, which is the molecular weight of air. Hence

$$c_p = 1.009 \frac{\text{watt-sec}}{\text{g-deg.}}$$

$$x = 1.400_5$$

When the temperature decreases, the specific heat of air increases. The increase is noticeable at —78 deg. cent. and reaches the value of about 5 per cent at —183 deg. cent. When the pressure is reduced to $\frac{2}{3}$ atmosphere, the increase of specific heat is still noticeable at — 183 deg. cent., but has a smaller numerical value (3 per cent). It appears, therefore, that qualitatively in the neighborhood of its point of condensation, air shows the same behavior that Knoblauch and Jakob, and later Knoblauch and Mollier, have found for steam.

According to Linde the specific heat c_p at pressure p and absolute temperature T may be represented by the specific heat c of the ideal gas state independent of the temperature, that is, for the case of infinitely small pressure, when the following equation holds good:

$$\frac{c_p}{c} = \left(1 - \frac{ap}{T^3}\right)^{-\frac{2}{3}}$$

The constant may be calculated from experimental observations of the Joule-Thomson effect. If p is measured in atmospheres, then for air $a = 21{,}500$. According to the tests of Linde this relation holds good for the case of small pressures down to the temperature of condensation of air.

With the aid of this formula it is possible to eliminate c and to determine from the specific heat $c_p = 1.009$ at room temperature and atmospheric pressure the specific heat c_p at equal or different pressure and at a lower temperature. One finds that under atmospheric pressure at — 78 deg. cent. $c_p = 1.013$ and from this value and the Linde equation the specific heat at — 183 deg. cent. is $c_p = 1.065$, while at a pressure of $\frac{2}{3}$ atmosphere and — 183 deg. cent. $c_p = 1.045$, all values being in watt-seconds per g-deg. Within small fractions of one per cent these figures equal with the values found experimentally. (*Zeitschrift für Sauerstoff- und Stickstoff-Industrie*, vol. 11, nos. 9-10, May 1919, pp. *d*)

TABLE 2

Temperature, deg. cent.	Specific Heat c_p	
	in watt-seconds / g-deg.	in g-calories / g-deg.
+20	1.009	0.240$_5$
−78	1.019	0.243$_2$
−183	1.058	0.252$_5$

VARIA

OIL VERSUS COAL FOR USE ON SHIPBOARD. The following statement in *Power* at the end of an article describing stokers for use on shipboard is highly significant.

The navies of the world will use oil regardless of price. So, too, will fast passenger ships. It is believed by many that there is not enough oil to warrant its wide use in the merchant marine for many years, although within recent weeks rich oil finds are reported from Colombia. Just now American coal is selling in Italy for $36 a ton. The freight rate is $22. So it is not bad business now to use oil-burning ships in the coal trade to Europe. Yes, the mechanical stoker for ships is here, and when oil again becomes high-priced or its supply alarmingly diminished, it will come into its own. (*Power*, vol. 51, no. 3, Jan. 20, 1920, pp. 86-89, 8 figs., *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society. The Editor will be pleased to receive inquiries for further information in connection with articles reported in the Survey.

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Departments of MECHANICAL ENGINEERING by members of The American Society of Mechanical Engineers are solicited by the Publication Committee. Contributions particularly welcomed are suggestions on Society Affairs, discussions of papers published in this journal, or brief articles of current interest to mechanical engineers.

Screwed Pipe Joints

TO THE EDITOR:

Very little attention is paid to the manner in which screwed pipe-thread joints are made. It is generally up to the pipe fitter to put red lead or some other kind of dope on the threads and then exert all his strength to screw the pipes together. When he comes to test the joints, however, he finds a goodly percentage of

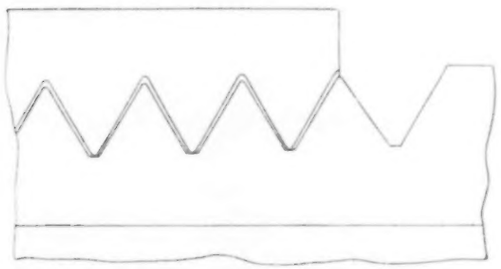


FIG. 1

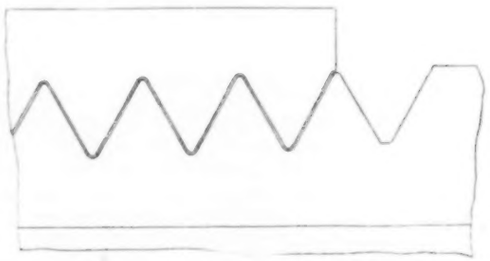


FIG. 2

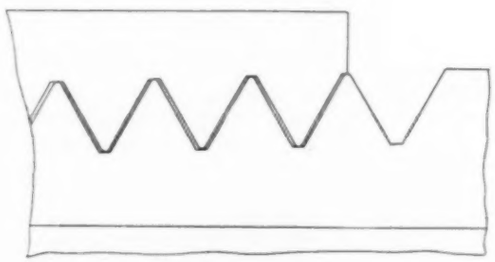


FIG. 3

them leaky. As a last resort he will apply a peening tool to close up the leaks, a thing that should not be done, as in most cases it only stops them for a short time. But the fault is not his, it is mostly the fault of the pipes and fittings—the way they are threaded.

In the first place, all pipe threads are supposed to be made to the Briggs Standard gage. It is almost impossible for the manufacturers to do this, as a tool made perfect to the Briggs Standard will not stay that way very long in practical work. It is most natural that the sharp point of the thread on the tap or die will wear first, as shown by the male part of Fig. 1, and, as it would be utterly impractical to discard a tap or die before the shape varied from the Briggs Standard shape by a reasonable amount of wear, there ought to be some allowance made first in the making of the tool and then in the working gage. For instance, a perfect female pipe and male pipe that have been threaded with tools that have cut a good many threads before, as in Fig. 1, will never make a good joint except by applying main force, which should not be done. If, however, the bottom of the female thread were flattened somewhat, as shown in Fig. 3, the pipes would screw together with very little force; the sharp points on the male and female threads would be of such shape that they would float in place, the sides of the threads would come together and a good joint would result throughout, as shown in Fig. 2.

It is an easy matter to keep the tool so it will make a thread as shown in Fig. 4 for the male pipe, and in Fig. 5 for the female. The width of the flat part of the thread could vary from 1/10 to 1/8 of the depth of the sharp V-thread, and a joint would always

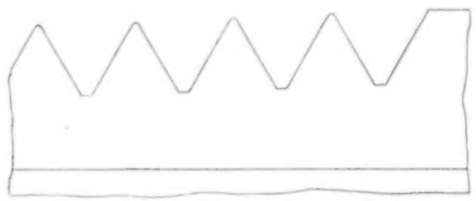


FIG. 4

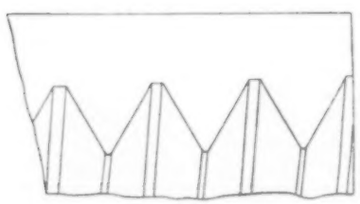


FIG. 5

be made by floating the sharp point of the thread against it. As a matter of fact, however, the flat of the thread will be a round fillet, as the sharp point of a tool will soon wear round, and if made flat it will still wear round after it has performed a small amount of work.

Manufacturers have been reluctant to admit that the threads on fittings and pipes are not perfect to Briggs Standard, and it is high time to overcome that difficulty by making the working gage so it will gage the sides of the threads and not ride at the bottom when the thread is not perfect. I have seen pipes and fittings gaged with a Briggs Standard gage that were apparently all right, but when screwed together they would not make a joint for the simple reason that the female thread would be too large and the male thread too small. The crests of both the male and female work gages should be flattened to an extent not less than the U. S. Standard thread flat or one-eighth the depth of sharp V-threads; in fact, if one-sixth were taken off it would be still better.

HENRY RITTER.

Cincinnati, Ohio.

Discussion of the Horsepower of Resistance

TO THE EDITOR:

A measure of performance of tractive machines which is convenient for broad generalizations is

$$\frac{\text{weight} \times \text{speed}}{\text{horsepower}} \text{ or } \frac{WV}{H}$$

For the battleship *Pennsylvania*, this coefficient has the value 47,000, based on shaft horsepower. A freight train with a resistance of 10 lb. per ton at 20 miles per hr. gives a coefficient of 75,000. In general, the value of the coefficient is $C = 750{,}000 \div R_T$, where R_T = resistance in lb. per ton of weight.

A man on a bicycle may realize a value of C around 40,000. For an average pleasure automobile, $C = 5000$. The lowest values of all are realized with airplanes, because these machines sustain as well as propel. The NC transatlantic hydroplanes give $C = 1900$ at 80 m.p.h. The usual range is from 1400 to 1800. High speeds always tend to reduce C, because power increases faster than speed.

Since for an airplane $H = dV^3(K_D A + K_P) \div 375$, the coefficient becomes

$$C = \frac{375W}{dV^2(K_D A + K_P)} = \frac{375W}{R} = \frac{375}{\tan \theta}$$

where R = total resistance, lb., and θ is the gliding angle. The coefficient in question is therefore (in homologous units) simply the reciprocal of the gliding angle. It should have a high value, as the gliding angle should have a low value. Since $R_T = 2000 R \div W$, $C = 750{,}000 \div R_T$, as above.

Efficient airplane flight seems, therefore, to involve high altitude (low d), a proper wing form, and low parasitic resistance. The question of altitude is influenced, however, by the falling off of engine power at high altitudes.

W. D. ENNIS.

New York, N. Y.

Economic Loss Caused by Rust

TO THE EDITOR:

The actual economic loss and wastage of steel and iron tools, machines, vehicles, agricultural machinery and implements, parts and supplies of all kinds, due to rust from moisture condensation and to corrosion from fumes, etc., must be enormous.

Are any data or statistics available which express this loss?

INDUSTRIALIST.

New York City.

WORK OF THE BOILER CODE COMMITTEE

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING, in order that any one interested may readily secure the latest information concerning the interpretation.

Below are given the interpretations of the Committee in Cases Nos. 262-266, inclusive, as formulated at the meeting of December 2, 1919, and approved by the Council. In accordance with the Committee's practice, the names of inquirers have been omitted.

CASE NO. 262

Inquiry: Does the term "equivalent pitch for cylindrical surface" as referred to in Par. 212*c* of the Boiler Code apply to the outside shell or to the inside shell?

Reply: It is the opinion of the Committee that this term in the formula of Par. 212*c* refers to the surface to be stayed, which in this case is the inside shell.

CASE NO. 263

Inquiry: a Is it the intention that Table 5 of the Boiler Code which specifies the maximum allowable stresses for stays and staybolts shall apply to iron as well as steel stays? Are sub-items *a*, *c* and *e* supposed to apply to iron as well as to steel?

b Is it assumed by the Boiler Code Committee that an ordinary expanded boiler tube has no holding power in the tube shell whatever? What holding power is a beaded tube or a welded tube supposed to have?

Reply: a Items *a* and *c* of Table 5 apply to iron as well as steel, but in accordance with the requirement of Par. 4, item *e* applies only to iron.

b It is the opinion of the Committee that tubes which are merely expanded in the tube sheets have a large initial holding power. However, under practical conditions of operation, where the seating of the tube in the sheet is disturbed, the holding power of tubes so attached is different. It was for this reason that the Code requires either beading, flaring or welding in of tubes. There have been many tests made on the holding power of tubes, the results of which may be found in technical literature and handbooks.

CASE NO. 264

Inquiry: What form of test will be required for the shell of a miniature boiler formed by the cupping and hot-drawing process from a sheet of firebox plate which meets the requirements of the Boiler Code? It is believed that the specifying of firebox boiler plate steel and subjecting each finished cupped and hot-drawn shell to an hydrostatic test, using the formula $P = 32{,}000t/D$, and the flattening test of a coupon cut from each cupped and drawn piece, this flattening test to go to 5 times the wall thickness, would be sufficient guarantee of the finished material and would be far more representative and better test than taking tests from the material before the cupping and hot-drawing operations.

Reply: It is the opinion of the Committee that if the firebox plate material from which the boiler shell is formed meets the requirements of the Boiler Plate Specifications of the Code, and if the shell is properly annealed after drawing, it may be considered as having met the requirements of the rules in the Boiler Code. The Boiler Code Committee has been informed that for proper annealing, the shell should be subjected to a temperature of 1550 deg. fahr.

CASE NO. 265

Inquiry: Is it the intent of Par. 25 of the Boiler Code that chemical limits for carbon are applicable only to firebox plate and not to flange plate?

Reply: The Specification for Boiler Plate Steel in the Code, which is in conformity with the similar specification of the American Society for Testing Materials does not specify any chemical limits for carbon in steel plate of the flange grade.

CASE NO. 266

Inquiry: Does not the reply given in Case No. 206 conflict with the rules in the Boiler Code for calculation of structural

members for the stiffening of unstayed portions on heads of boilers?

Reply: It was not the intent of the Boiler Code Committee in Case No. 206 to indicate that the stiffening effect of the members used to attach the braces to the head could be added to the value of the braces, in determining the maximum allowable working pressure for which the design was constructed.

SPECIALIZED CURRICULA IN ENGINEERING COLLEGES[1]

By A. A. POTTER, MANHATTAN, KAN.[2]

THOSE who are responsible for the conduct of engineering departments at universities or colleges are urged by some to develop specialists, and by others to make the curricula broad. Some alumni, particularly during their first few years after graduation, advocate courses to meet the needs of the special industries, others feel that engineering schools are now devoting too little time to basic principles and facts.

Mr. Benjamin G. Lamme, chief engineer of the Westinghouse Electric and Manufacturing Company, in discussing technical training for engineers before the Pittsburgh Section of the American Institute of Electrical Engineers in 1916, made the following remarks concerning specialization:

> There has been quite a fad for specialization in engineering training. The writer's personal opinion is that specialization in college training is not advisable, except possibly in a very general way. There has been a false idea in many schools that if a man specialized along some individual line of work it would advance him more rapidly when he leaves school for active work. The writer almost never asks the student in what field he specialized. . . . In college training the time spent on commercially practical details is usually largely wasted, as it may give the student entirely wrong ideas. . . . The colleges should aim to develop analytical ability, imaginative faculty, ability to do independent thinking. . . . A broad general training is most desirable for the man who has ability to do something in the world.

The majority of engineering colleges are devoting their chief attention to curricula in civil engineering, electrical engineering and mechanical engineering. There seems also to be considerable demand for men trained in mining engineering, chemical engineering, architecture and architectural engineering. Several institutions are also offering curricula leading to degrees in agricultural engineering, ceramic engineering, flour-mill engineering, highway engineering, railway engineering and industrial engineering. Specialized curricula have also been proposed in business engineering, petroleum engineering, aeronautical engineering, etc.

An investigation has been made of the ground covered at twenty-four representative institutions in their civil, electrical and mechanical engineering curricula with results as follows:

About fifteen per cent of the total time is devoted to mathematics, twelve per cent to physics and chemistry, eight per cent to English and other modern languages, ten per cent to mechanics and hydraulics, three per cent to economics and business organization, five per cent to elementary engineering drawing, about thirty per cent to specialized engineering subjects, and about fifteen per cent to related engineering subjects.

The specialized subjects in a civil-engineering curriculum usually include: surveying, masonry and foundations, bridge design, railways, highways, drainage irrigation, water supply, sewage disposal, and concrete construction. The related engineering subjects include shop practice, elements of power engineering, and elements of electrical engineering.

In the electrical-engineering curriculum the specialized subjects usually include: theoretical electricity, direct- and alternating-current machinery, electrical measuring instruments, power engineering, telephony, electric railways, and electric design. The related engineering courses are usually thermodynamics, shop practice, machine design, surveying and factory organization.

In the mechanical-engineering curriculum the specialized subjects include: machine design, shop practice, thermodynamics, power engineering, power-plant design, heating and ventilation, refrigeration and factory organization. The related subjects are electrical machinery, structural design, and surveying.

An analysis of the various specialized curricula will reveal the fact that they differ mainly by name from those in civil, electrical or mechanical engineering. Such specialized curricula are usually chosen by the adventurous and poorer students who are attracted by good-sounding names.

Employers of graduates from engineering schools are usually not concerned with the name of degree the young engineer holds. The large electrical manufacturers do not differentiate between those trained as electrical and those trained as mechanical engineers. A representative of a telephone company stated that his company is willing to accept men trained in any engineering course, but that he does not care to select men from schools who claim to train telephone engineers.

If it were possible to predict the line of work the student will enter after graduation, certain specialization might be justified. Even in such cases a broad engineering training would be preferable, as the young engineer will find that his work will necessarily specialize him and will so absorb his energies as to leave him very little time to acquaint himself with related specialties. Records of graduates from engineering schools show that, while the majority follow some branch of engineering, comparatively few remain in the particular field which they had expected to enter when at college.

Dean M. E. Cooley, President of The American Society of Mechanical Engineers, in the September 25, 1919, issue of the *Engineering News-Record* makes the following statement:

> Engineers are not wholly blameless for the position in which they find themselves—a responsibility which the engineering colleges must share. They have devoted altogether too much time to professional subjects. In their zeal to fit themselves for work in the field of their choice, non-technical subjects which make for breadth have been sacrificed. Thus they are narrow, are fenced in so that neither can they look out nor can others look in.

Close observation of the records of hundreds of graduates from engineering schools leads the author of this paper to the opinion that better results would be accomplished if the majority of engineering colleges would devote their energies to two curricula, one dealing mainly, in its applications, with static engineering and the other with dynamic engineering. In the first curriculum should be included the courses now in the civil-engineering curricula of our best schools and should familiarize the student with the broad principles underlying the design and construction of railways, highways, irrigation and drainage projects, masonry, concrete, sanitation, and business administration. In the dynamic-engineering curriculum should be included the fundamental courses now given in the electrical- and mechanical-engineering curricula, with considerable emphasis on factory management, power engineering and business administration.

Curricula in mining engineering, chemical engineering and architecture should be offered only by a small number of institutions. There may also be need for a few colleges to offer graduate courses or short courses which will prepare men for certain specialized work in the industries. Admission to such courses should be limited to men who have had considerable practical experience.

Experience indicates that broad engineering education will enable the college graduate to reach greater usefulness in his profession than will specialized technical training.

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[1] Address delivered before meeting of the Mid-Continent Section of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS at Bartlesville, Okla., October 30, 1919.

[2] Dean, Division of Engineering, Kansas State Agricultural College, Manhattan, Kan.

According to Albert Reeves, General Manager of the National Automobile Chamber of Commerce, 1,892,000 motor vehicles were built in the United States in 1919, of which 305,000 were motor trucks. Two hundred and sixty manufacturers were engaged in this production, employing 580,000 workmen. The wholesale value of these vehicles was, in round figures, $1,808,000,000. There are approximately 7,100,000 motor vehicles registered in the United States, of which 700,000 are motor trucks, these latter having displaced, it is estimated, over 3,500,000 horses.

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Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

Mechanical Engineers to Meet Next May at St. Louis

The Spring Meeting of The American Society of Mechanical Engineers is to be held at St. Louis, May 24 to 27, the first meeting being on Monday of the week of the convention in accordance with the plan followed so successfully at Detroit last year.

In view of the interest throughout the Mississippi Valley and in the territory contributory to it, one session will be devoted to a discussion of river-transportation problems, and the movement now under way for the development of transportation on the Mississippi River, with New Orleans as the port for shipment of goods to South American and other countries. Another session will be devoted to the subject of the Valuation and Appraisal of Industrial Properties, using as material the papers presented at the last Annual Meeting, upon which discussion is being solicited by the Committee on Meetings and Program. Papers are also in prospect on fuels, oil engines, measurement of the flow of water, transmission of heat, pumping engine tests, aeroplane design, etc. A paper is to be presented by the recently elected Honorary Member of the Society, A. C. E. Rateau, of France, on Turbo-Compressors for Increasing the Power of Aeroplanes at High Altitudes. It is also expected that papers will be presented by the Mid-Continent Section, representing the oil districts of Oklahoma, on subjects relating to the distribution and use of oil for industrial purposes.

St. Louis is a rapidly growing industrial center, with one of the most progressive Chambers of Commerce in the United States, engaged in educational work for the increase of production in agriculture and industry, both locally and throughout the state, and for the improvement of industrial conditions. A large housing undertaking is under way upon which there will be a contribution at the meeting. An immense plant being erected by the Chevrolet Motor Company is one of the influential factors in bringing about this movement. There are numerous manufacturing plants, some of large size and several of the most modern equipment, undertaking unusual lines of work of interest to members of the Society.

The parks of the city, with the outdoor municipal theater and the Art Museum in a location remarkable for its beauty and extent of view, are among the finest in the country. The hotel accommodations are good and modern, and altogether the city is an ideal place for a meeting of engineers, and a whole-hearted welcome is assured on the part of the local members and their many friends of the city, both within and without the profession. St. Louis is proud of her accomplishments industrially and as a civic community, and justly so. The Committee on Meetings and Program and the officers of The American Society of Mechanical Engineers are gratified at the opportunity which the city has extended to the membership for a convention which promises to be one of the greatest in the history of the Society.

What Is Engineering?

The Committee on Development of the American Society of Civil Engineers, in its report to the Board of Directors presented on October 14, submitted the following definitions of engineering:

1 Engineering is the science and art of directing the great sources of power in Nature to the use and convenience of man.

2 Engineering is an art and a science. It is a science in so far as physical laws are its base, and an art in so far as in the application of these laws the things designed and constructed develop the spirit of progress, the creation of wealth, and the well-being of all peoples.

Engineering is generally divided into four major divisions, viz., civil, mechanical, electrical, and mining.

The practice of engineering requires knowledge of physical laws, forces, and the materials of Nature.

The professional engineer is one who by reason of special training, education, and experience is qualified to design and direct the construction of engineering work in one or more of the major divisions of engineering.

3 Engineering is the creative science and art of applying economically the materials and forces of Nature to the use and convenience of man.

4 Engineering is the science of industrial effort, and the science and art of applying this effort for the welfare of the public.

An engineer is one versed in the science and art of industrial effort made for the purpose of public welfare.

Civilization Follows Transportation

Many years ago Professor Metchnicoff, of the Pasteur Institute, Paris, better known for his work in the field of biology and micropathology, published a book dealing with the history of ancient civilization.

He showed that civilization followed the course of the great rivers, which was only natural in the light of our modern knowledge. Great cities as well as even such crude manufacture as existed in the ancient world required the movement of goods, such as food and building and raw materials, and in a roadless world the rivers presented the only available cheap means of communication.

In this country the early settlements followed the same water paths. The Hudson and Ohio rivers, and later on the Mississippi, were the great liquid roads carrying the early American commerce and settlers.

As civilization moved, however, and the wealth of nations increased, the rivers were not sufficient to carry on the commerce of the world and canals were dug, at first as outlets for rivers into more convenient directions or as connecting links between important rivers, and later on as more or less independent means of communication. This represents the basic transportation tendency of the 18th century and the early days of the 19th century. The historical Manchester Canal in England is one of the best illustrations of this phase of the transportation problem in Europe, and the Erie Canal, which practically made an empire state of New York, serves as a good example of the application of

this same principle to conditions throughout the entire United States.

But water transportation is at best only a makeshift. It is slow and, when created artificially, by no means cheap. In North America it is closed to users for several months in the year. Further, water carriers have to be large in order to be economical, which in turn means that the goods shipped have to be either in bulk character or have to be accumulated until there is enough to fill a steamboat. All this corresponds to the stage of economic development when industry was still moving slowly.

The next stage was the creation of the railroads, which have been the means of opening immense regions of the country devoid of rivers or canals. The great American Northwest, the mining regions of the central Rockies, and the wealthy states of the Pacific slope could not have been opened to settlement or commerce without the railroads.

In the 75 years of the railroads' existence, however, it has been found that they also have certain limitations. While they represent the most economical means of transportation over distances in excess of, say, 200 miles and for shipments not below a certain relatively moderate bulk, an insistent demand arose for an economical means of transportation of goods below the transportation range of the railroads, especially for distances less than 100 miles, or what might be called urban-circle deliveries. When a legitimate demand on a large enough scale arises, it is usually promptly satisfied, and the motor truck came to the relief of those who needed that type of transportation.

One more transportation question has been looming up for the last 25 years at least, and that is transportation between widely scattered localities where there are neither roads nor rivers, and where the comparatively small volume of traffic does not justify the construction of railroads. In the sparsely populated mining regions of South America, in the outlying settlements of Africa, in the islands of the Pacific, there was a demand for a way of rapidly conveying passengers and comparatively small amounts of goods and for exporting the products of local industries, such as rubber, gold, and other minerals. This problem cannot yet be considered to be definitely solved, but a promise of its solution lies in the recent rapid progress of the aeroplane and dirigible. The whole history of the improvement of the means of conveyance shows, however, that as means of transportation have improved civilization has followed in its way. As the rivers helped to build up ancient cities and the earlier towns of the Western Hemisphere, so the Erie Canal has helped to build the Empire State, the railroads have opened Minnesota, the Dakotas and Manitoba, the motor trucks are now opening up the farming communities throughout the country, and the aeroplanes will make possible the development of the rich mines of Central and South America and South Africa; and in the far distance loom still greater possibilities of which it would now perhaps be premature and but a flight of fancy to discuss.

The "Mysterious Mr. Smith"

The story of how the new buildings and some of the equipment of the Massachusetts Institute of Technology in its new site on the Charles River Basin, Cambridge, Mass., were made possible by the munificent contributions of a certain "Mr. Smith" is generally known by all who have kept in touch with technical education in this country.

Who this Mr. Smith was, however, has been a zealously guarded secret, until at a recent jubilee dinner of the alumni of the Institute, to celebrate the successful completion of a drive for a $4,000,000 endowment, the real name of this benefactor of the M. I. T. was disclosed as Mr. George Eastman, the "Kodak King" of Rochester, N. Y.

In 1914 the Massachusetts Institute of Technology celebrated the fiftieth anniversary of its chartering and marked the occasion by deciding to move from its outgrown buildings which had become a landmark in the Back Bay district of Boston, to its present location in Cambridge. Later, President Maclaurin of the Institute, himself a physicist of renown, spent a day at the works of the Eastman Kodak Company, where he was greatly impressed by the high order of scientific attainment in the laboratories and manufacturing departments of this great plant. Mr. Eastman was not at Rochester at the time and Dr. Maclaurin therefore wrote him asking for a conference with regard to the problems and opportunities of the Institute and its possibilities for the development of scientific work. They met at dinner in New York, and Mr. Eastman was so interested in the project for rebuilding Technology that he at once gave $2,500,000, expressing the desire that a comprehensive plan for the new buildings should be followed and the usual incoherent, piecemeal construction for such institutions avoided.

As the work progressed, $1,000,000 more was added, and just before the dedication of the new monolithic structure in which the Institute is now housed, he offered five dollars for every three that others contributed up to a limit of $2,500,000, an offer which was fulfilled. Still other donations were subsequently made and finally, when the drive for the $4,000,000 endowment above referred to was completed, Mr. Eastman matched it with a sum of equal amount. His total gifts to the Institute have amounted to $11,000,000, all of which, with the exception of a quarter of a million specifically for chemical engineering equipment was given anonymously.

Mr. Eastman preferred to keep the real name of the donor a secret in order to avoid notoriety and only disclosed it because of the legal requirements incident to the transfer of stock made necessary at the time of his latest gift of $4,000,000. Naturally there has been a great deal of guessing as to who was "Mr. Smith." Among those suspected were Frick, Rockefeller, Vail and DuPont, the latter a Technology alumnus who has contributed large sums to his Alma Mater under his own name. There also were many amusing incidents in this connection, of people who had announced definitely that they, or some one of their friends, were the man; and of wealthy suspects who met and accused each other of keeping under cover, and who separated believing that the other fellow was a colossal bluffer.

The authentic announcement of Mr. Eastman places him as one of the greatest supporters of technical education in America, and it is a pleasure to know that the gifts have come from one who, through his own experience, has full appreciation of the value of such education.

Conference on National Safety Codes

A general conference on safety codes was called by the Bureau of Standards at Washington, for December 8. This conference was attended by representatives of a very large number of organizations interested in the preparation of standard safety codes, including engineering societies, trade organizations representing all phases of industry and City and State commissions. By a vote taken at this conference, the American Engineering Standards Committee was asked to request the National Safety Council, the International Association of Industrial Accident Boards and Commissions, and the Bureau of Standards acting together to appoint an Advisory Committee of fifteen for three purposes, viz.,

(1) to determine the order of priority in the development of safety codes
(2) to recommend to the A. E. S. C. suitable sponsor and joint sponsor bodies
(3) to make report, after preliminary study, not later than February 1.

This matter was taken up by the American Engineering Standards Committee at its meeting on January 3 and the Committee took favorable action on the recommendation of the Conference. A committee of fifteen was immediately organized and held a meeting in Washington on January 9, at which the following members were present:

F. D. Patterson, representing Pennsylvania Department of Labor and Industry.
W. C. L. Eglin, representing National Electric Light Association, Committee on Safety Rules and Accident Prevention.
M. G. Lloyd, representing Bureau of Standards, Safety Section.

Royal Meeker, representing U. S. Bureau of Labor Statistics.
L. W. Chaney, representing U. S. Bureau of Labor Statistics.
Dana Pierce, representing Underwriters' Laboratories.
W. P. Eales, representing The American Society of Mechanical Engineers.
E. B. Rosa, representing Bureau of Standards.
A. W. Whitney, representing National Workmen's Compensation Service Bureau.
S. J. Williams, representing National Safety Council.
P. G. Agnew, Secretary, American Engineering Standards Committee was also present.

The Committee first organized itself with Dr. E. B. Rosa as Chairman and Dr. Royal Meeker as Secretary. It then adopted the name of "National Safety Code Committee."

A total of 63 Safety Codes on as many subjects were scheduled by Dr. Rosa for consideration. Those for which The American Society of Mechanical Engineers was suggested as sponsor, are as follows:

Elevators and Escalators
Stationary Steam Boilers
Non-fired Pressure Vessels
Boiler Room Equipment and Operation
Steam Engines and Turbines
Internal Combustion Engines
Engine-Room Equipment and Operation.
Ladders
Locomotives

A number of other codes were discussed, some of which in all probability will be assigned to this Society, but no definite decision on these was reached at the time of this meeting of the Joint Advisory Committee.

Technical Papers at Annual Meeting of Society of Automotive Engineers

A number of interesting professional papers were presented at the annual meeting of the Society of Automotive Engineers, held in New York, January 6 to 8. In a paper on Preignition of Spark Plugs, Stanwood W. Sparrow of the U. S. Bureau of Standards, described tests on specially prepared spark plugs, which indicate that one of the main causes of preignition is the lack of proper cooling of a spark-plug element, and in some cases improper design of the engine itself. The lack of proper cooling of the spark-plug elements may be due either to improper design of the plug or to subsequent causes preventing its proper preparation.

Major George E. A. Hallett, chief of Power-Plant Section, Engineering Division, Air Service, Dayton, Ohio, presented general data on the use of superchargers for aircraft engines. The conclusion to which the author comes is that supercharging in principle is of value to several classes of military aeroplanes, as well as to certain types of civilian planes. As a graphic illustration of the advantage of supercharging, it was pointed out that at 25,000 ft. altitude a supercharged 250-hp. engine will deliver as much power as a 1000-hp. engine without supercharging apparatus.

Interesting considerations on Dilution of Engine Lubricants by Fuel in Automotive Engines were presented by Gustave A. Kramer, of the U. S. Bureau of Standards. Among other things were described experiments to determine the effect of dilution by fuels on the viscosities of lubricants, the fuels being diluted either by an average grade of fuel gasoline or by commercial kerosene. The author suggested the use of an oil renovator as part of the engine itself.

The important problem of the use of low-grade fuels in the automotive engines was discussed briefly by J. G. Vincent, vice-president in charge of engineering, Packard Motor Car Company, Detroit, Mich., who suggested among other things, the use of a special manifold for preheating fuel with an automatic method of regulating the heat. The principle of the device is the employment of a difference in pressure existing on either side of the carburetor butterfly valve; a small amount of the combustible mixture is caused to pass through a passage which is in parallel with the main carburetor passage whereupon the mixture is burned in a suitable burner and the burned gases are allowed to mix with the incoming main supply to the engine above the throttle.

Notwithstanding the great progress made in the application of the constant-volume-type internal-combustion engine to use in road vehicles, an increased amount of attention has been paid recently to the problem of adopting steam to the same purpose. Louis L. Scott, chief engineer, Standard Engineering Company, St. Louis, Mo., presented a description of a Steam Automotive System which it is said has already been applied both to passenger cars and to trucks.

L. H. Pomeroy, consulting engineer, Cleveland, Ohio, discussed the trend of automotive-engine design in the light of the application of modern views of gasoline-engine thermodynamics, and noted recent improvements in mechanical efficiency, in engine balancing, in carburetion and the progress which has been made in the utilization of low-grade fuels.

Of special interest were also the following: Aluminum Piston Design, E. G. Dunn; The Measurement of Vehicle Vibrations, Benjamin Liebowitz; Needs in Engine Design, Frank H. Trego; Bettering the Efficiency of Existing Engines, Hugo C. Gibson; Mixture Requirements of Automotive Engines, O. C. Berry; Springs and Spring Suspensions, E. Favary; The Velocity of Flame Propagation in Engine Cylinders, R. K. Honoman and Donald McKenzie; and Composite Fuels, Joseph E. Pogue.

The report of the Iron and Steel Division proposed specifications for low-tungsten steel for inlet and exhaust valves, nickel steel for case-hardened parts, malleable-iron castings for general automotive purposes, and high-chromium steel for exhaust valves in aeroplane engines. The composition recommended for low-tungsten steel expressed in percentage was: carbon, 0.50 to 0.70; manganese, not to exceed 0.30; phosphorus, not to exceed 0.035; sulphur, not to exceed 0.035; chromium, 0.50 to 2.00. Malleable castings were specified to be produced by air-furnace, open-hearth, or electric-furnace process; the minimum tensile strength permitted was 45,000 lb. per sq. in. and a minimum elongation of 7.5 per cent in 2 in. The suggested composition in percentage for high-chromium carbon steel was: carbon, 0.20 to 0.40; manganese, not to exceed 0.50; phosphorus, not to exceed 0.035; sulphur, not to exceed 0.035; chromium, 11.50 to 14.00; silicon, not to exceed 0.30.

New York Automobile Show

The New York Automobile Show, held at the Grand Central Palace in the week of January 3 to January 10, left a mixed impression on an engineer who tried to gage the state of the industry from the exhibits.

The first impression was decidedly encouraging. Both the exhibits and the attendance at the show indicated a thoroughly healthy state of the industry. Practically all the old companies were represented, and there were a considerable number of newcomers who had either made good already, or who gave fair promise of doing so as soon as they had had time enough to arrive at this result.

The art of exhibiting automobiles has made a big advance since one or two years ago. The general disposition of the exhibits this year was good, and there was far less crowding than marked the exhibits of the previous years. More sectional models than ever were shown, operated by electric motors so as to give a chance to the public and the engineers to see the inside construction. This latter was a rather unexpected feature as in the last few years the study of engine development has been such that the ability of the engine to perform is now taken for granted. On the other hand, however, it may be that the technical education of the public has proceeded to such a point that a larger number than ever want to know the reason why and refuse to take anything for granted in mechanical lines.

More and more attention is being paid to body refinements, and the coach work of the cars shown at the Grand Central Palace exhibited a gratifying high form of development.

All this is highly encouraging, but some of the promises of the past two years do not seem to have been fulfilled, at least as far as one may judge from what was shown at the Grand Central Palace.

For nearly two years the automotive industry was in the service of the Government, engaged in assisting it in the strenuous work of building up in record time the great American war machine. This necessarily forced automobile engineers into entirely new lines of work. Some of them made shells, others aeroplanes and aeroplane motors; still others the fine instruments needed for the Ordnance and Navy Departments. It was confidently expected that this would bring a flood of new ideas into the automobile field just as it did in Europe, and from this point of view the show was to a certain extent disappointing.

There were exhibited no really new developments. The engines, the chassis construction (with some exceptions), the accessories still follow the conventional lines, and, notwithstanding even the impending shortage of gasoline, nothing at the show indicated that the industry is anything like prepared to meet this great condition.

It would be unfair, however, to exaggerate this fact, or to attach too great importance to it, for two reasons. In the first place, during the year and a half elapsed since the war the American automobile industry has gone through a period of tremendous strain. Following the great task of reconverting the industry back to the peace basis were the grave labor disturbances both in the automobile plants themselves, and still more so in the accessory plants supplying automobile plants with castings, bodies and parts, which created conditions anything but favorable to the undertaking of new developments on a large scale.

That in the face of all this the automobile industry has been able not only to meet the demands of the market, but to bring into the product a number of minor improvements, clearly shows the great vitality of the industry and the genius of the men directing it, and it would have been difficult to expect basic developments under such conditions in such a comparatively short time. That important research work is going on in practically all the larger companies is an open secret, but the results of this work were not shown at the Grand Central Palace, and from this point of view it cannot be said that the show represented the actual state of the industry.

While, however, no radical improvements were shown, a trained eye could easily discover the influence of war work in many directions. The finish of parts, the machining, and especially the attention paid to the balancing of moving parts, is far superior to anything that we have seen in the industry in the past.

What has been said about the Passenger Car Show at the Grand Central Palace, largely applies also to the Motor Truck Show which was going on simultaneously at the Jerome Avenue Armory.

Of the minor improvements, the following may be noted:

At the Passenger Car Show the spring suspension was employed in such a manner that a spring base of 130 in. is secured with a wheel base of only 100 in.

At the Commercial Car Show, the Shacht Motor Car Company exhibited a truck with a 10-speed transmission which is secured by using a regular five-speed transmission (four ahead and one reverse) and a sub-transmission doubling the range of the main transmission. So far this arrangement has been applied to 5-ton trucks only where apparently there may be the greatest demand for it.

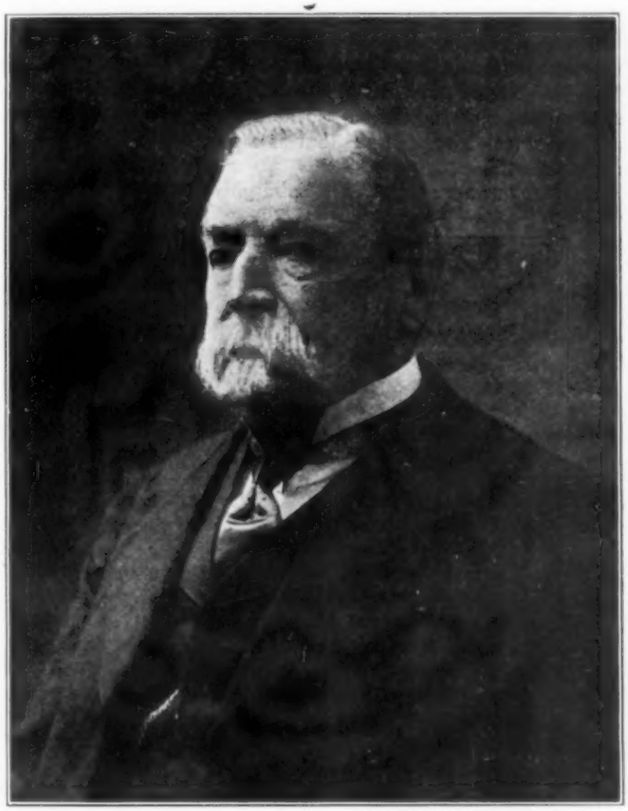
The fundamental impression left by the thousands of exhibits at the show would indicate that the industry is a perfectly healthy one and that greater things may be confidently looked forward to in the very near future in the way of mechanical road transport.

This is of importance not only to the automobile industry generally but to the country at large, as transportation is a measure of the progress of civilization.

Anatole Mallet

Anatole Mallet, Honorary Member of The American Society of Mechanical Engineers, died in Nice, France, in October, 1919. He was one of the few men whose name became the designation of a standard type of apparatus in a great industry. Born in 1837 at Carouge, and graduated in 1858 from the Central School of Arts and Manufactures in Paris, Mr. Mallet devoted all his attention for a number of years to problems in civil engineering. He was first connected with the Bureau of Direction of the General Company of Railroad Materials in France, and subsequently with the work on the Suez Canal. In 1864 he was engineer for the company which undertook the dredging of ports of Italy.

In 1867 he engaged for the first time in mechanical engineering, giving particular attention to steam engines with double



ANATOLE MALLET

expansion. The first application of this system to locomotives was made in 1876, when he introduced the first two-cylinder compound locomotive, which operated on the line from Bayonne to Biarritz. A fuel economy 20 per cent superior to that given by the standard types of the time was attained, which at once placed the inventor in the foremost ranks of locomotive designers.

The great success of the compound locomotive led to a material increase in the size of the tractive unit and to the development successively of three- and four-cylinder compound locomotives. In this way it became evident that the limit of size of a locomotive of rigid construction, especially on lines with sharp curves, would soon be reached, and the problem arose of building a locomotive of still larger size which would have the necessary flexibility. This problem was solved by Mallet in the design of the articulated locomotive, an invention which made his name familiar to every railroad engineer throughout the world. The most powerful locomotives now in existence are of the Mallet articulated type.

He was a member of the Society of Civil Engineers of France, The Society for the Encouragement of National Industry of France, and The Franklin Institute of Philadelphia. The French Society of Civil Engineers awarded him the Schneider prize in

1902, and the annual prizes in 1909 and 1911. He was made a Knight of the Legion of Honor in 1885 and promoted to Officer in 1905. The Institution of Mechanical Engineers of London awarded him a gold medal in 1915.

In addition to carrying on important engineering work, Mr. Mallet took an active part in the work of the French Society of Civil Engineers. From 1880 to within a few months of his death he was editor of the *Chronicle* of the Bulletin of the Society and furnished it with numerous technical notes and important memoirs, the last of which, treating of The Practical Evolution of the Steam Engine, earned for him the honors conferred by the Society.

Death of the President of the Massachusetts Institute of Technology

Richard C. Maclaurin, President of the Massachusetts Institute of Technology, died of pneumonia at his home in Cambridge, Mass., on January 15. He was only 49 years old, but had gained an international reputation, not only as an educator and an administrator of large affairs, but as a physicist, a mathematician and a jurist.

Dr. Maclaurin was born in Edinburgh in 1870. His early boyhood was spent in New Zealand, whence he returned to England to complete his preliminary education in English schools. He later was graduated from St. Johns College of the University of Cambridge, where he also received the advanced degree of Master of Arts, the thesis work for which was in higher mathematics.

RICHARD C. MACLAURIN

He next spent several months in the United States and Canada studying educational institutions. Again returning to England he reëntered Cambridge, this time to study law, and was awarded the McMahon Law Studentship, the most highly valued in the university for law students.

In 1898 Dr. Maclaurin was appointed professor of mathematics in the University of New Zealand, became a trustee of the university, and took an active part in the organization of technical education in the colony. In 1903 he became Dean of the Faculty of Law in the university, which office he held for four years. In 1907 he was invited to take the chair of mathematical physics at Columbia University, New York, and a year later was made head of the department of physics.

In 1898 the degree of Doctor of Science was conferred upon Professor Maclaurin by Cambridge University for his researches in pure science, and again in 1904 he was honored with the degree Doctor of Laws by the same university for his achievements in the study of law.

In 1908 Dr. Maclaurin was appointed president of the Massachusetts Institute of Technology at a time when its finances were low, its buildings inadequate, and the call for the education at this institution of students from all over the world was very great. The new president succeeded in drawing together into a unified, enthusiastic body the corporation and faculty of the institute, and the alumni and students. By concerted action the movement was started which resulted in the new and greater Technology now located in its magnificent buildings on the Charles River in Cambridge, Mass. One of the fruits of this movement was a gift by T. Coleman du Pont of $500,000 toward the purchase of the site for the buildings. How Dr. Maclaurin, backed by the alumni, succeeded in raising the additional funds needed for the completion of the plans for expansion is told in another article in this number. The culmination of this was the announcement at a jubilee dinner by the alumni on January 10 of the success of the campaign for a $4,000,000 endowment, supplemented by a gift of an equal amount by George Eastman of the Eastman Kodak Company. Just previously, however, Dr. Maclaurin had been stricken by illness, and it was not permitted to him to tell the alumni personally of this greatest achievement of his life. A few days later he died—indeed a tragedy, his death coming at the height of his career, just as he had completed the foundation for the great educational work which the institute is destined to accomplish with its splendid equipment.

AN IMPROVED WEIR FOR GAGING IN OPEN CHANNELS

(*Continued from page* 88)

One word more, however, the writer allows himself in relation to the formulæ for weir discharge. It had been his intention not to evolve any formula, but to present the result of his experiments in the form of a table, arranged somewhat as are tables of logarithms, so that quantities could always be read at a glance from the data observed. No one cares for the formulæ by means of which logarithms are computed; their use would not be furthered by a study of them. No more need a Power Test Code contain formulæ for weir discharge; a table would answer its purposes more fittingly.

But the exceeding simplicity of the weir formula appurtenant to the form of weir herein presented upset this plan. Such a weir does not need so much as a table to look up or to compute its discharge. All one has to do is to measure the length of the weir and then multiply it by 5.5 and by the difference in head.

But there remains the question, why 5.5? Why not 20, or any other quantity? And for the mitigation of the stated laudable curiosity, further experiments will no doubt be undertaken in the course of time; and much ink of disquisition may yet be set adrift.

THE TESTING OF FARM TRACTORS

(*Continued from page* 102)

as a machine for converting gasoline into tractive force would remain as determined by the laboratory tests. These tests may be denominated consumer's tests.

The first and its corresponding field experiments will have determined the overall efficiency of the tractor as a power machine.

The second will differentiate these results and distribute the various factors of efficiency or inefficiency throughout the machine. It will serve to separate the performance of the engine from that of the transmission and other moving parts, and in so doing will perhaps be more satisfactory to the manufacturer. This we may denominate a producer's test.

EMPLOYEES' REPRESENTATION IN MANAGEMENT OF INDUSTRY

The Economic Questions Involved, as Summarized by Dr. Royal Meeker, U. S. Commissioner of Labor Statistics, at Conference on Industrial Relations Held at Chicago, Together with Other Discussion

THE annual convention of the American Economic Association was held in Chicago on December 29 to 31 concurrently with those of the American Association for Labor Legislation and the American Sociological Society. The question of industrial unrest formed the topic of a great number of the addresses in the three programs. Particularly at a joint session of the Association for Labor Legislation and the Economic Association the discussion of this question was brought to a focus by Dr. Royal Meeker, United States Commissioner of Labor Statistics, who, in his address on Employees' Representation in the Management of Industry, asserted that neither the English Whitley scheme nor the various plans which have been introduced in American industries constitute anything more than an initial experiment in the direction of a solution of industrial unrest.

In Great Britain the Whitley system of organizing industries into national and district joint industrial councils and works committees was adopted at the instance of the Government. Up to date, national joint industrial councils have been set up in some fifty industries, besides the councils established in the Government departments for both manual and clerical employees. These national joint councils, according to Dr. Meeker, are analogous to the roof of a house suspended in mid-air with no supporting side walls or foundations upon which to rest. Only three industries have set up complete Whitley systems of joint industrial representation of employers and employees with a national council and district councils for the industry and works committees for individual shops, and these three industries are relatively insignificant, namely, match, rubber and pottery manufacturing.

Dr. Meeker divided the different types of shop committees and work councils in this country into three distinct groups: (1) closed-shop committees of union workers chosen exclusively by union men affiliated with national or international unions; (2) open-shop committees composed of workers chosen by the votes of all workers who have been employed in the shop a required length of time; (3) open-closed-shop committees chosen by all workers qualified to vote in a shop that is closed against trade unions and which may or may not have a local plant or corporation organization of the workers. There is, in fact, little fundamental variation, he said, in the published statements of the objects sought and the plans of organization as between group and group.

Comparing the different views of Americans and of the British, Dr. Meeker pointed out that respecting labor organization the position of organized employers and employees is exactly reversed in Great Britain. We today are where the British were about thirty years ago. The question of national unions versus plant unions was fought out in Great Britain and won by the workers. British employers were obliged to accept the result and bargained collectively with the representatives of the national unions. During the war the workers rebelled against this system, insisting that wages, hours and shop conditions should be negotiated for each shop by the local shop committees. The employers stood up valiantly for the established order, and insisted that they would have nothing to do with local shop committees, but would bargain collectively only with truly responsible and representative bodies, the executives of the national trade unions. American employers, equally valiant for the established order, will have nothing to do with irresponsible, unrepresentative officials of national trade unions and insist on bargaining collectively with representatives of the workers who know the local situation and who are chosen from the shop where a dispute is pending. One of the biggest questions to be settled, in Dr. Meeker's opinion, is whether employees' representation is to be local and under the direct control and domination of the employer, or whether it is to be nation- or world-wide and under the control of the workers themselves, or whether the general public will insist on being a party to every collective agreement so as to prevent the employers and employees from agreeing too agreeably and charging the bill to the ultimate consumer.

If workers are to be admitted to actual participation, Dr. Meeker suggested they must participate to some extent in the losses as well as the gains of industry. A practical method of payment would be to guarantee for each position a minimum wage which must be paid regardless of any losses which the business may suffer. In addition to the minimum, a bonus should be provided varying according to the contribution of the workers in cutting down labor costs, in reducing costs of management, in decreasing spoilage of material, in decreasing wear and tear on machines and tools, in improving quality of product, in increasing business, or in any other way. This would obviate the objection to most bonus schemes that the worker is penalized or rewarded for the inefficiency or the good judgment of the managers.

Labor unrest, in the present-day meaning of the term, is, in Dr. Meeker's opinion, a natural and inevitable result of the industrial revolution, machine production, absentee ownership of industrial establishments, and the centering of industrial management in the hands of managers of finance whose offices are in the big banks and office buildings of the centers of finance and trade. Strikes in the modern sense were practically unknown until industrial units had grown to such a size as to erect formidable barriers between the workers on the one side and the responsible owners and managers on the other. Lack of interest in work, he said, grows out of absentee ownership. The absent industrial landlords, interested only or principally in dividends, have employed experts, scientific managers, to produce a substitute for the old-time workman's interest in his work. The theoretical ideal of maximum output with minimum expenditure of effort which can be figured out by mathematical formulæ and pictured on charts, is never attained in practice. A much more imperfect layout, which leaves much to the ingenuity and initiative of the individual workmen, in practice always achieves better results.

The present-day movement for industrial democracy, Dr. Meeker continued, is a partial recognition of the fundamental psychological phenomenon that industrial fatigue is not simply an engineering question to be stated mathematically in foot-pounds per hour or even a physiological question having to do with calories used up in the body. Work is hard primarily because it is uninteresting and monotonous, or easy because it demands ingenuity or skill. Paradoxical as it seems, the way to make work easier is to make it harder by requiring more of the workmen. In so far as scientific management has resulted in merely breaking processes up into component parts, segregating so far as possible the purely muscular and mechanical operations from the creative and planning functions, so-called "efficiency" has resulted in the most disastrous inefficiency.

Willard E. Hotchkiss, Chicago, took issue with various of Dr. Meeker's remarks and maintained that it has not been established as a fact that the workers object to repetitive jobs. Economists, he stated, have created a complete literature on the labor problem which is based on *a priori* conclusions. In his opinion little progress will be made in the direction of a solution of our labor difficulties until principles are worked out by inductive reasoning.

Prof. Ira B. Cross, University of California, raised the question whether the introduction of works councils did not constitute a dangerous economic policy. He cited the circumstance which attended the introduction of the works-council plan in a large American industry. The workmen, who were doubtful as to the advantages of the scheme, asked the advice of radical labor leaders and were told to support it on the theory that eventually it, in conjunction with similar councils in other industries, would form the basis for establishing a soviet form of government.

Prof. Frank W. Blackmar, University of Kansas, in an address on A Working Democracy, emphasized that neither an autocracy of capital nor an autocracy of labor can be permanently successful. A similar idea was discussed by A. W. Small, University of Chicago, who, in a paper on Democracy and Labor, read before the Sociological Society, described "laborocracy" as being as objectionable as any other kind of autocracy, and as inevitably doomed.

An optimistic view of the labor situation was presented by Matthew Woll, vice-president of the American Federation of Labor. He addressed the Sociological Society on Labor and Democracy, and the Economics Association on Labor and Immigration Questions. He asserted that the bulk of organized labor is loyal to America and its institutions and observed that while there have been a few spectacular labor disputes, like the steel strike and the coal strike, there have also been thousands of readjustments of wages and working conditions through direct negotiations between employers and organized labor without strikes.

John A. Fitch of *The Survey*, and S. K. Ratcliffe, a well-known English journalist, delivered interesting talks at a joint session of the Association for Labor Legislation and the Sociological Society, on the general subject of Democracy and Industrial Life.

Another general subject which was given much attention was the prospect for international labor legislation.

A more extensive account of these conventions is given in *Iron Age* for January 8, 1920, from which these notes have been prepared.

GOVERNMENT ACTIVITIES IN ENGINEERING

Notes Contributed by The National Service Committee of Engineering Council[1]

A New Board of Surveys and Maps

AN executive order recently issued by President Wilson creates a new Board of Surveys and Maps, the purpose of which shall be to coördinate the activities of the various map-making agencies of the Government, to standardize results and to avoid unnecessary duplication of work. This order is the outcome of a suggestion which Engineering Council made to President Wilson in a letter dated July 1, 1919, which pointed out that the official map work of the United States was being prosecuted by twelve separate and distinct Federal agencies, the majority of which are making maps for special purposes, and which are of little value for any other purposes. Furthermore, some states, counties, cities, and private organizations are also engaged in this work and since each of the Federal agencies and the others above mentioned follows methods developed in its own surveys, the result is precisely that which might be expected. There is no agency in the United States which has authority to coördinate the work.

The Council therefore advised the creation of a "Board of Surveys and Maps" consisting of a representative from each of the present Federal map-making agencies, together with representatives from well-qualified map-using agencies, which would be vested with authority to work out a plan of standardization and coördination of the work of the Government.

This letter was referred by the President to the Secretary of War with the request that a conference of representatives of the twelve map-making agencies named by Engineering Council be called to consider the suggestion in its several practical aspects. Representatives of these agencies and of the Forest Service and U. S. Hydrographic Office accordingly held a series of conferences at Washington, D. C., from September 15 to 29, inclusive, and the following engineering and scientific societies were invited to send representatives to the meetings to present their needs:

Engineering Council
The American Society of Civil Engineers
The American Institute of Mining and Metallurgical Engineers
The American Society of Mechanical Engineers
The American Institute of Electrical Engineers
The American Association of State Geologists
The American Association of State Highway Officials
The National Research Council
The Association of American Geographers
The American Geographical Society
The Geological Society of America
The National Geographic Society

Ten of these organizations were represented at the conference on September 22, but since the time available was not sufficient to formulate and present their views during the conference, it was agreed that the above-named organizations would present their recommendations to the permanent body proposed by the conference.

The report of the conference, submitted to the President through the Secretary of War on September 30, 1919, includes a general survey of the subject; a statement of the map needs and of the map-making activities of each of the fourteen organizations represented at the conference; the practical program outlined by the Interdepartmental Committee on Aerial Surveying; suggestions for consideration by the proposed Board of Surveys and Maps; and estimates for the completion of primary control of the United States by the U. S. Coast and Geodetic Survey and for the completion of the topographic mapping by the U. S. Geological Survey.

The Board of Surveys and Maps, according to the executive order, will be composed of representatives of the fourteen organizations represented at the conference. The order further provides that the individual members of this Board shall be appointed by the chiefs of the various organizations named and shall serve without additional compensation.

The Board is also directed to make recommendations to the several Departments, or to the President, for the purpose of coördinating all map-making and surveying activities of the Government and to settle all questions at issue between executive departments relating to surveys and maps insofar as their decisions do not conflict with existing laws.

The Board is authorized to establish a central information office in the U. S. Geological Survey for the purpose of collecting, classifying and furnishing to the public information concerning all map and survey data available.

A permanent organization of the Board was effected on January 13 when representatives from each of the Departments met and elected O. C. Merrill, Chairman (Chief Engineer, Forest Service, Department of Agriculture); William Bowie, Vice-Chairman (Chief, Division of Geodesy, Coast and Geodetic Survey, Department of Commerce); and Colonel C. H. Birdseye, Secretary (Chief Geographer, Geological Survey of the Department of Interior).

It is hoped that this concentration of mapping work will permit larger proportionate appropriations for the country's mapping program under the direction of the Geological Survey. In bringing this matter to the attention of the President, Engineering Council realized the great value of making reliable maps of the whole country available to every branch of the engineering profession in the simplest and most direct way. This will be accomplished through the central information office provided in the Geological Survey to receive and distribute Government and public map data. Thus, if proper appropriations can be obtained and put to work under the Geological Survey, the engineers of the country as well as the Government departments will be greatly benefited.

In this connection it is pertinent to state that the National Service Committee of Engineering Council in coöperation with all state geologists are urging prominent engineers in every congressional district to bring pressure to bear upon their congress-

[1] Engineering Council is an organization of national technical societies created to consider matters of common concern to engineers as well as those of public welfare in which the profession is interested. The headquarters of Engineering Council are located in the Engineering Societies Building, 29 West 39th Street, New York City. The Council also maintains a Washington office with M. O. Leighton, chairman of the National Service Committee in charge. This office is in the McLachlen Building, 10th and G Streets, Washington, D. C. The officers of Engineering Council are: J. Park Channing, *Chairman;* Alfred D. Flinn, *Secretary.*

men to vote sufficient funds for topographic mapping. This has been accomplished by selecting a prominent engineer—members of the Founder Societies—in each congressional district and urging them by direct appeal to request their senators and representative to support a $600,000 appropriation for topographic mapping.

The state geologists have coöperated by sending these engineers complete information of the local conditions, so that they may be thoroughly conversant with their "back-home" requirements, and thus be more forceful with their men in Congress. Further, most of the state geologists are endeavoring to get increased state appropriations for this important work, which will have to be matched by an equal Federal appropriation in most cases before they become available for expenditure.

The estimates submitted by the Secretary of the Interior call for an increased mapping program to cost $600,000 annually, instead of $500,000 which was last year's estimate. It will be recalled that the last Sundry Civil Appropriation Bill provided $375,000 for topographic mapping, which was less by $50,000 than prewar annual appropriations for this work. This year's estimate contemplates a program that will complete topographic mapping in twelve years instead of the one hundred years which will be required if the old appropriation is not increased.

Water Power Bill Passes Senate

Although it was stated in the last issue of MECHANICAL ENGINEERING that the Senate, during its next session, would take up, and possibly dispose of, several bills of interest to engineers, such action has not, up to the time of going to press, taken place.

The Senate, upon reconvening on January 5, after the usual holiday session, first devoted its attention to the Water-Power Bill, discussion of which lasted nearly a week for the debate both on the bill itself and on many of its amendments was very active. The bill finally passed the Senate with a majority of three to one, substantially as passed by the House, except as to certain conditions of renewal to take effect after 50 years' license. In reporting the bill to the Senate the Committee explained and clarified the definitions of "reservations," "navigable waters" and "costs." A proportionate license fee not exceeding twenty-five cents per horsepower is proposed, which is to defray costs of the administration of the act. Fair rentals are to be charged for Government dams and other Government property on water-power sites. The bill also provides that in case the United States does not exercise the right to take over the works, the license tendered shall be "on reasonable terms" and "which is accepted" by the original or the new licensee. This provision was thought necessary to make it certain that capital would invest under the law. A provision for severance damages also appears in the bill.

This bill now goes to a committee composed of members from both the House and Senate. This is for the purpose of settling on points of difference. The Senate is represented by Senators Jones, Nelson, Smoot and Fall (Republicans) and Bankhead and Myers (Democrats). The House conferees have not as yet been appointed. It is not expected, however, that further delay will be occasioned, and that not more than two weeks will be occupied in getting the bill through this Joint Conference Committee.

Technical Work at Bureau of Standards

Bulletins dated January 9 on the progress of experimental work that has been started at the Bureau of Standards are as follows: (1) Accuracy of Electrical Measuring Instruments; (2) Electron Tubes in Radio Telephone Transmitting Sets; (3) Recent Radio Publications; (4) Industrial Safety Standards; (5) Measurement of Thermal Expansion of Various Materials; (6) Service Tests of Concrete Floor Treatments; (7) Consistency and Time of Set of Next Cement Determined by New Method; (8) Slag as an Aggregate for Concrete; (9) Flat-Slab Investigation; (10) Manufacture of Automobile Crankshafts; (11) Investigation of Electric Welding; and (12) of Chilled-Iron Car Wheels.

Because of the current nature of these investigations the results are not generally put in printed form, but complete data on the results of the work to date are always available on application to the Bureau of Standards or the National Service Committee in the Washington office of Engineering Council.

Colonel Beach New Chief of Engineer Corps

Colonel Lansing H. Beach, U. S. A., has been appointed Chief of Engineers, replacing General William M. Black, retired. Colonel Beach's appointment came as a complete surprise to many, as he had not been publicly mentioned for the place. He is a native of Iowa and a graduate of West Point and has held the rank of Colonel since 1913. While Colonel Beach is best known for the work he has done in connection with Mississippi River projects, he has had the varied service which comes to all Engineer Corps officers who have spent most of their lives in its service. He has done extensive engineering work on Great Lakes projects and was in charge of the important improvements of the harbors of Baltimore and Jacksonville. More recently he has been stationed at Cincinnati in charge of the construction of the system of locks and movable dams being constructed in the Ohio River. Colonel Beach has been prominently identified with the development of inland waterways, as a member of the Mississippi River Commission and as a member of the Board of Engineers for Rivers and Harbors and as an advisor to the Waterways Division of Railroad Administration.

TAYLOR SYSTEM IN GERMANY

The following advertisement of a firm of efficiency engineers taken from a German trade paper, gives a pithy expression of the benefits claimed for scientific management. The translation of the advertisement is also given in similar form.

Für Arbeitgeber und Arbeitnehmer:

Erhöhung des Einkommens und der Leistungsfähigkeit. Einschränkung jedes überflüssigen Kräfteverbrauchs.

Der einzige Weg zur Erhöhung der Löhne bei Verminderung der Produktionskosten.

Für die gesamte Wirtschaft:

Erhöhung der Produktion mit den jetzigen Einrichtungen.

Qualitäts-Erzeugung und Steigerung der Leistungsfähigkeit bei Verminderung der Erzeugungskosten.

Erhöhung des tatsächlichen Arbeitswertes durch ergiebigere Ausnutzung aller aufgewendeten Mittel: Zeit, Kraft, Material und Geld.

Für den Wiederaufbau Deutschlands die Rettung!

Das ist das Taylor-System!

The Taylor System Means

To the Employer and Employee:

Higher Income and Efficiency

Reduction of Unnecessary Consumption of Effort

The Only Way to Raise Wages and at the Same Time Reduce Cost of Production.

For the Entire Industrial System:

Increase of Production With Now Available Facilities

Quality Production and Increase of Efficiency at Lower Cost of Production

Increase of the Actual Value of Work by a More Efficient Utilization of Employed Means, Namely, Time, Effort, Material and Money.

For the Reconstruction of Germany—Salvation.

NATIONAL DEPARTMENT OF PUBLIC WORKS ASSOCIATION HOLDS SECOND CONVENTION

Engineers Urge Congress To Pass Jones-Reavis Bill Consolidating Federal Public Works

NATIONAL interest in the bill now before Congress to replace the present Department of the Interior by a National Department of Public Works, and thus bring under one bureau all the engineering activities of the Government, was greatly intensified by a two-days' conference of the National Department of Public Works Association held at the Willard Hotel, Washington, D. C., January 13 and 14. Ninety-five delegates representing the leading engineering societies and organizations of the country, with a total combined membership of nearly 90,000, took part in the discussions and proceedings of the conference.

Four sessions were held. These were chiefly given over to reports of officers and committees and discussion of the Public Works Department bill now before Congress. A communication from Governor Lowden of Illinois dealing with the organization of the public works in that state was presented, and Representative Reavis, one of the authors of the bill, and Brigadier-General R. C. Marshall, chief of the Construction Division of the United States Army, also addressed the convention.

General Marshall pointed out that there are at present 27 separate and distinct Federal agencies engaged in the construction of public buildings, 18 in building roads, and 18 in work relating to hydraulics, river and harbor work. He was accordingly of the opinion that a Department of Public Works could accomplish a most constructive step in the history of Government work by placing all Federal construction under control of a single bureau with a single method of accounting and a single bureau of purchase.

M. O. Leighton, chairman of the Executive Committee, opened the convention by briefly reviewing the history of the Association since the inception of the movement by Engineering Council at a meeting held last April. As originally planned the Association was made up solely of technical men, but the movement has since become so general that its supports are now convinced that it should have active backing from those outside the profession. Chairman Leighton expressed these sentiments in his opening address as follows:

> We here assembled are asking Congress to do the obvious thing. Give the Government a business-like organization. Coördinate the functions so that the processes of Government business shall dovetail. Cut out the wastes and the duplications. Abolish the rivalry between departments. We advocate a Department of Public Works not merely to secure technical symmetry in our Federal organization, desirable as that end may be, but our advocacy in its essential features is an attempt to stop some of the waste.
>
> When this organization was set up at Chicago I think that none of us—certainly not the speaker—had an adequate idea of the scope of the movement. We saw a loose and inefficient public works organization, divided and subdivided into many different provinces. As technical men we knew how organically wrong that was. Of the wastes and inefficiencies we were well aware. With the necessity for a coördinated structure by virtue of which the technical and semi-technical fields of the Government could be rendered efficient and business-like we were profoundly impressed. But that our effort, our idea, our legislative bill would become the cornerstone of a structure embodying efficiency on all Departments of Government we could hardly foresee. As an organization our effort is still focused on a Department of Public Works and that alone. But we realize that with that principle established—that example set—reform in other provinces of Government business activity will occur by the mere logic of events. We are pioneers.
>
> This is the reason why our project for a Department of Public Works strikes straight home to the business man, the manufacturer, the contractor, and the merchant, all of whom are represented here today. The technical men who met at Chicago last April to set up this organization built better than they knew. While the project retains all the virtues that appealed to us when it was launched—of technical excellence, of rational Government organization, of economy and efficiency, we now see that it reaches to national and to business prosperity, to the fiscal welfare of the nation, to the individual welfare of the productive business.
>
> We may as well recognize and admit the fact that individual initiative in America will not continue to be that spontaneous thing that it has been in the past if the rewards are to be divided and a part of them are to be wasted in the support of a chaotic Government business organization. The burdens of every business organization in the country are magnified by Government business inefficiency. We want no good and proper thing to be withheld from our Government nor in turn by our Government.

References to the efforts of engineering organizations to create a Department of Public Works have frequently been made in the columns of MECHANICAL ENGINEERING. The bill which creates this new Department is commonly known as the Jones-Reavis Bill, and the details of the changes which it proposes in the executive machinery of the Government were discussed in the August issue, page 709. Briefly the bill creates a Department of Public Works which is to replace the Department of the Interior and thus assemble under one head all the engineering activities of the Government. Such bureaus of the Department of the Interior as are of a non-engineering character will be transferred to existing appropriate departments.

The first convention in this movement was held in Chicago last April, and since that time various state committees have been at work within their own districts. A roll call of these various state committees held during the convention showed that considerable effective work has been done, chiefly, however, in the southern and western states. Two states reported that their entire congressional representation had pledged their support of the bill. The eastern states, and particularly those which represent the large industrial centers have, however, made but little progress toward obtaining congressional support. This condition of affairs was not altogether expected, and in the opinion of many, considerable effort will be necessary to overcome the opportunities thus lost.

Following the roll-call the Jones-Reavis Bill itself was discussed. The chief objections centered around Section 3 which provided for the transfer of the Bureaus of Education, Pensions, Indian Affairs and other similar non-engineering bureaus of the Department of the Interior to existing department of the Government. In order to place before the public its position on this and other controversial section of the bill the convention adopted the following resolution defining its position:

> 1 The National Public Works Department Association must, under its articles of organization, confine its efforts solely to the creation of a Department of Public Works.
>
> 2. Section 3 of H. R. 6649-S. 2232 (the Jones-Reavis Bill) has nothing to do with public works. The only reason for its presence in the bill is that some departmental disposition must be made of the non-engineering bureaus in the Interior Department.
>
> 3 It is manifest that the numerous organizations which become affiliated under the name of National Public Works Department Association for a common public-works purposes do not, by so doing, commit themselves with respect to any other question, national or otherwise. Therefore each affiliated organization may have and is entitled to express its views as to said Section 3 of the bill without in any way qualifying its approval of the remainder of the bill.
>
> 4 The National Public Works Department Association, as such, is therefore unable either to approve or to disapprove the specific assignments of bureaus in the said Section 3, and in advocating the bill before committees of Congress the agents of this Association are to be instructed to present this fact in an unmistakable way.
>
> 5 The National Public Works Department Association suggests to all affiliated organizations that they present to Congress their own individual views with respect to said Section 3, either through the legislative agents of this Association or otherwise.
>
> 6 The officers and directors of this Association are instructed to have the foregoing statements printed in suitable form and circulated as one of the campaign documents issued in support of this movement.

The second day of the conference was largely devoted to interviews with senators and congressmen, committees representing the several states having been appointed for this purpose the day previous. Reports of these interviews indicate that the proposed bill will doubtless be favorably reported, although it must not be inferred that success is altogether assured. On the contrary, the task of securing sufficient support to finally pass the bill has only just begun, and an undue optimism at this time may result in failure. The widest publicity possible should accord-

ingly be given the measure and every engineer should make it a personal matter to lend his support to this exceedingly important bill.

The Committee on New Organization, of which Calvin W. Rice, Secretary of The American Society of Mechanical Engineers, is chairman, rendered a report in which it recommended that the scope of the appeal of the association be enlarged to include the business, professional and social bodies and that all such activities be accorded executive representation in the movement.

The Committee also suggested that there be a committee of the Association in every state; that each state committee use every existing organization which is in any way enlisted by this movement.

The Committee stated that while the present organization of the Association has been adequate and admirable up to the present time it should nevertheless be enlarged as indicated. What it needs is popular support in effort and in subscription.

The knowledge that the present officers have of the needs of the work should be accepted and such expansion should be granted as the officers and Executive Committee may recommend.

During the final session of the convention the financial needs of the Association were discussed at some length, and it was made very evident to those present that, if the Association was to continue, this issue must be met and settled. Heretofore the various member societies of the Association have contributed but little, the expenses of the work being largely met by individual subscriptions. The Committee recommended that each society be asked to assess its members at the rate of one dollar per man.

ENGINEERING FOUNDATION REPORTS PROGRESS IN RESEARCH

THE second formal publication of the Engineering Foundation, scheduled to appear in October but delayed by the recent printers' strike in New York, has just been issued. Engineering Foundation is one of the three departments of the United Engineering Society, and was made possible by the presentation to that organization of a sum of money as a trust fund, the interest of which is to be used in the promotion of engineering research. This gift came from Ambrose P. Swasey, past-president and honorary member of The American Society of Mechanical Engineers. In 1914, in fulfilment of his desire to advance the work of the engineer and add to the accumulated facts which serve to guide him in his undertakings, he gave the United Engineering Society $200,000, the income of which should be used "for the furtherance of research in science and engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind." In September 1918 Mr. Swasey added $100,000 to the endowment, making the present total $300,000.

The organization meeting of the Engineering Foundation Board was held on April 15, 1915. As at first constituted, the Board had eleven members, elected by United Engineering Society and each serving for a term of three years or less. By amendment of the By-Laws of United Engineering Society, April 25, 1918, the Board was enlarged to sixteen members, and by this amendment an executive committee of five members was also provided.

The Engineering Foundation Board is charged with the responsibility of administering funds placed at its disposal. It supports no project the merits of which have not been demonstrated by competent inquiry. In the development of such inquiry it is fortunate in possessing the coöperation of the National Research Council, an organization having world-wide scientific affiliations. While the Engineering Foundation Board reserves to itself the right to choose, initiate, and conduct under its own immediate direction such researches as may commend themselves to its membership, it is at the present time making extensive use of certain channels established by the National Research Council, notably the Council's Division of Engineering.

The National Research Council is an organization of American scientists, engineers and educators, established in April 1916 under the Congressional charter of the National Academy of Sciences, given in 1863. It comprises representatives of national scientific and technical societies, chiefs of technical bureaus of the Army and Navy, heads of governmental bureaus engaged in scientific research, representatives of other research organizations, and other persons whose aid may advance the objects of the Council. The Council is organized in thirteen divisions of two classes, six dealing with the more general relations and activities of the Council and seven with science and technology. The Division of Engineering, under this second class, includes twenty-eight members, at least five of whom are members of the Engineering Foundation, and one of whom is the Chairman of that body. A more detailed history of the National Research Council will be found in MECHANICAL ENGINEERING for July 1919, p. 631.

In June 1916 the Engineering Foundation Board decided to devote its resources to the National Research Council for one year, beginning September 1916. The close coöperation between the two organizations which resulted from this decision was found to be so mutually helpful that at a meeting of the Foundation Board in September 1917 it was resolved "to continue the coöperation between the two bodies in all practicable ways that may be now, or may become, mutually available, such ways consisting of the interchange of helpful suggestions, advice, information, office representation and similar facilities, and in addition a recognition of community of purpose that shall promote in the field of engineering research increasingly intimate relations between engineering and science."

In total, sixty members of the Founder Societies are members of National Research Council, and of these, eight are members of the Foundation Board. The total membership of the National Research Council is about 175. One member of the Engineering Foundation Board and its secretary, and 31 additional members of the Founder Societies, are members of the National Research Council in divisions other than the Division of Engineering and on its Executive Board. Engineers have therefore an influential position in the Council and a large measure of responsibility for its success.

The Engineering Division of the Council has 18 committees, each charged with a specific line of research and together covering a wide variety of subjects of interest to engineers and the industries. It is with this division, as stated before, that the Engineering Foundation is at present most closely associated.

In August 1919 the Executive Committee of the Foundation took action to support preliminary investigations in a number of subjects recommended by the Division.

Research in fatigue phenomena of metals is to be conducted in the laboratories of the Engineering Experiment Station of the University of Illinois under the direction of Prof. H. F. Moore. The Experiment Station shall have the right to publish the results in full as a bulletin of the station, but in addition shall prepare a brief, comprehensive statement suitable for publication in the journals of the engineering societies. A progress report of the Committee on Fatigue Phenomena of Metals, which summarized the facts and theories relating to fatigue failure appeared in the September 1919 issue of MECHANICAL ENGINEERING, p. 731.

From approximately fifty suggestions made to date, the Engineering Foundation Board has selected for investigation six subjects. These are: (1) wear of gears, (2) spray camouflage for ships, (3) directive control of wireless communication, (4) weirs for measurement of water, (5) establishment of a testing station for large water wheels and other large hydraulic equipment, (6) mental hygiene of industry. Investigations 1, 3, 4 and 6 are in progress; the other two have been completed.

An investigation concerning existing industrial research laboratories in the United States has resulted in assembling and classifying some information about each of approximately 250 laboratories connected with the industries, which give whole or part time to industrial research and development. This information is being prepared for publication under the joint auspices of the Engineering Foundation and the Division of Industrial Relations of National Research Council.

CLASSIFICATION AND COMPENSATION OF ENGINEERS

Engineering Council Approves Final Report of Committee

IN April 1919 Engineering Council organized a Committee on Classification and Compensation of Engineers, whose object it was to secure better conditions of employment for engineers by classifying engineering positions into several grades, and determining the relative salaries of each. The Committee decided to confine itself to a consideration of engineers engaged in railroad, state, county and municipal, and federal activities and a main committee with three sub-sections was accordingly appointed with chairmen and personnel as follows:

COMMITTEE ON CLASSIFICATION AND COMPENSATION OF ENGINEERS:
Arthur S. Tuttle, *Chairman*, Deputy Chief Engineer, Board of Estimate and Apportionment, New York, N. Y.
Francis Lee Stuart, Consulting Engineer, New York, N. Y.
John C. Hoyt, Chief, Division of Water Resources, U. S. Geological Survey, Washington, D. C.
Charles Whiting Baker, Consulting Editor, *Engineering News-Record*, New York, N. Y.
M. O. Leighton, Chairman, National Service Committee of Engineering Council, Washington, D. C.

Railroad Section:
Francis Lee Stuart, *Chairman*
Frank H. Clark, Consulting Engineer, New York, N. Y.
Bion J. Arnold, Consulting Engineer, Chicago, Ill.

State, County and Municipal Section:
Arthur S. Tuttle, *Chairman*
M. M. O'Shaughnessy, City Engineer, San Francisco, Cal.
F. W. Cappelen, City Engineer, Minneapolis, Minn.

Federal Section:
John C. Hoyt, *Chairman*
John S. Conway, Asst. Commissioner of Lighthouses, Washington, D. C.
Oscar C. Merrill, Chief Engineer, Forest Service, Washington, D. C.

From time to time during the year partial and preliminary reports dealing with the work of the sub-committees have been submitted and printed in MECHANICAL ENGINEERING. The main committee has now completed its investigation and submitted its final report to Engineering Council and the complete and definite classification for engineers in federal, state, county and municipal and railroad service was approved by Engineering Council at its meeting on December 18, 1919.

The extracts from this report which follow include a classification of engineers into eight grades, five professional and three sub-professional, and a statement of the necessary qualifications for each; a comparison of the results of this latest investigation with those reported in 1917 by a committee of the American Society of Civil Engineers; and a summary of the returns from the questionnaires, with average ages of incumbents, average salaries in federal, state and municipal service and average salaries recommended by the engineers in charge.

FINDINGS AND CONCLUSIONS OF THE COMMITTEE

The investigations have shown the lack of any adequate or consistent employment policy with respect to professional engineers. This is evidenced by the following conditions which are believed to be largely responsible for the unsatisfactory status of men engaged in this class of work:

1 Absence of any uniform system of grading of positions
2 Lack of uniformity in titles of positions with respect to duties
3 Inequalities in compensation for positions of the same grade
4 Generally inadequate compensation for services rendered.

To the end that these conditions may be corrected and proper and equitable conditions of employment established, the following principles and practices are recommended by the Committee, though not yet acted upon by Engineering Council.

1 Positions should be classified in accordance with the type of work, and with the character of the duties to be performed and the qualifications necessary for their performance, as indicated by a system of grading.

2 Within the salary limits fixed for each grade, there should be a system of advancement through the grade based upon experience gained in the position and upon proof of increase in the proficiency of the employe in performing the duties of the grade.

3 Promotions from grade to grade should depend upon the existence of a vacancy in the higher grade and proof that the employe is qualified to fill the vacancy.

4 The determination of salary adequate to procure for and retain in engineering work a high class of employes, should take into account and properly weigh the following considerations:

a The capital invested, both in money and in time, in obtaining the requisite fundamental training
b The amount and character of experience and the degree of personal ability required
c The relative value of the classes of work to be performed
d The amount paid for similar service in other lines of work
e The amount necessary to enable the employee to maintain a standard of living commensurate with the general standards of the community for positions of similar dignity and responsibility.

5 In the interest of an adequate social policy, no position likely to be occupied by individuals of an age to assume family responsibilities should fail to pay an amount sufficient to permit the maintenance of the average family in reasonable decency and comfort.

6 In the interest of the employes as a whole and of the employer, a system should be established by which employes who fail to maintain satisfactory standards of service should be removed, transferred, demoted, or retired as may be equitable in the circumstances.

CLASSIFICATION OF ENGINEERING POSITIONS IN FEDERAL, STATE, COUNTY, MUNICIPAL AND RAILROAD SERVICES

The grades proposed, which appear to be well adapted to use not only in all of the services represented but also for all other forms of engineering activities, have been divided into two classes, the Professional Service being deemed to include men who have received an engineering degree from an educational institution of recognized standing or who have obtained similar qualifications through practice of the profession and by mastering the fundamentals of engineering science, while the Sub-Professional Service includes assistants with at least a high school education, who enter upon the practice of the profession in the performance of responsible duties for which an engineering training is not essential, but who through experience and study may fit themselves for the higher grades. The classification is as follows:

PROFESSIONAL SERVICE

GRADE 1 CHIEF ENGINEER

Duties: To act in chief administrative charge of a technical organization, or of a main division thereof; to determine the general policies of the organization under the limitations imposed by law, regulation, or other fixed requirement; to have final responsibility for the preparation of reports, cost estimates, designs, and specifications and for the construction, maintenance, or operation of engineering works or projects; to have full charge of the collection and presentation of data for and the conduct of valuation proceedings; to conduct or direct the most comprehensive lines of engineering research.

Qualifications: Training and experience of a character to give substantial evidence of engineering knowledge and ability or of executive capacity of highest order along lines of work similar to those involved in the positon to be occupied and of at least twelve years' duration, of which at least four years shall have been spent in duties of Engineer, or their equivalent, and at least five years in responsble charge of important work or projects. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing or, in absence of such degree, at least four years of additonal experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additonal experience.

GRADE 2 ENGINEER

Duties: Under general administrative direction and within the limits of the general policies of the organization, to have responsible charge of and to initiate and determine policies for a major subdivision of an organization; to prepare for final executive action reports, cost estimates, designs, specifications, and valuation studies and data; to have immediate charge of the construction, maintenance, or operation of engineering works or projects of major importance; to conduct or direct major lines of engineering research; or to furnish for executive action expert or critical advice on engineering works, projects or policies.

Qualifications: Active professional practice or executive charge of work for at least eight years, of a character to demonstrate a high degree of initiative and of ability in the administration, design, or construction of engineering work or projects of major importance, of which at least three years shall have been spent in duties of Senior Assistant Engineer, or their equivalent, and at least three years in responsible charge of work. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing or, in absence of such degree, at least four years of additional experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additional experience.

GRADE 3 SENIOR ASSISTANT ENGINEER

Duties: Under general administrative and technical direction, to be in responsible charge of an intermediate division of an organization; to exercise independent engineering judgment and assume responsibility in studies and computations necessary for the preparation of reports, cost estimates, designs, specifications, or valuations; to have immediate charge of the construction, maintenance, or operation of important engineering works or projects; or to conduct or direct important lines of engineering research.

Qualifications: Active professional practice or executive charge of work for at least five years, of which at least three years shall have been spent in duties of Assistant Engineer, or their equivalent, with at least one year in responsible charge of work. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing or, in absence of such degree, at least four years of additional experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additional experience.

GRADE 4 ASSISTANT ENGINEER

Duties: Under specific administrative and technical direction, to be responsible for the conduct of the work of a minor subdivision of an organization; to collect and compile data for specific items of engineering studies; to take immediate charge of field survey projects and of the design and construction of minor engineering work; to lay out and develop work from specifications and to supervise the work of a drafting or computing force; or to conduct specific tests or investigations of apparatus, material, or processes.

Qualifications: Experience for at least two years in duties of Junior Assistant Engineer or their equivalent. Fundamental training equivalent to that represented by professional degree granted upon the completion of a standard course of engineering instruction in an educational institution of recognized standing or, in absence of such degree, at least four years of additional experience. The completion of each full year of such standard course shall be considered the equivalent of one year of such additional experience.

GRADE 5 JUNIOR ASSISTANT ENGINEER

Duties: Under immediate supervision, to perform work involving the use of surveying, measuring, and drafting instruments; to take charge of parties on survey or construction work; to design details from sketches or specifications; to compute and compile data for reports or records; to inspect or investigate minor details of engineering work; or to perform routine tests of apparatus, material, or processes.

Qualifications: No experience required other than that involved in securing a professional degree upon the completion of a standard course of engineering instruction in an educational institution of recognized standing; but in absence of such degree, a high school education or its equivalent is required and at least four years' experience in the use of surveying, measuring or drafting instruments, or the computation and compilation of engineering data, together with evidence of a knowledge of the fundamentals of engineering science sufficient, with further experience, to qualify for the higher professional grades. The completion of each full year of such standard course of engineering instruction shall be considered as the equivalent of one year of experience.

SUB-PROFESSIONAL SERVICE

GRADE 6 SENIOR AID, OFFICE

Duties: To supervise the plotting of notes and maps, and to direct the work of a drafting or computing squad.

Qualifications: Experience for at least five years in tracing, lettering, drafting, and computing, of which at least three years shall have been spent in the duties of draftsman. Education equivalent to graduation from high school. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required, with the provision, however, that at least one year shall have been spent in the duties of draftsman.

GRADE 6 SENIOR AID, FIELD

Duties: To direct work of field party on surveys or construction; to keep survey notes and engineering records; to supervise construction or repair work; to direct the work of computing surveys and estimates; to direct the work of making minor engineering computations.

Qualifications: Experience for at least five years in the use and care of surveying instruments, of which at least three years shall have been spent in the duties of instrumentman. Education equivalent to graduation from high school. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required, with the provision, however, that at least one year shall have been spent in the duties of instrumentman.

GRADE 7 AID, OFFICE

Duties: To prepare general working drawings where design is furnished; to plot notes and prepare maps; to design simple structures; to make computations and compile data for reports and records; to check plans, surveys, and other engineering data.

Qualifications: Experience for at least two years in tracing, lettering, drafting and computing. Education equivalent to graduation from high school and familiarity with the use of the slide rule, and of logarithmic and other simple mathematical tables. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required.

GRADE 7 AID, FIELD

Duties: To run surveying instruments and to adjust and care for same; to compute surveys and estimates; to make minor engineering computations; to inspect incidentally construction or repair work.

Qualifications: Experience for at least two years in the duties of rodman. Education equivalent to graduation from high school and familiarity with the construction, operation, and care of surveying instruments. The completion of each full year of a standard course of engineering instruction in an educational institution of recognized standing shall be considered as the equivalent of the experience otherwise required.

GRADE 8 JUNIOR AID, OFFICE

Duties: To trace and letter maps and plans; to make simple drawings from sketches and data; to make minor calculations.

Qualifications: Education equivalent to graduation from high school.

GRADE 8 JUNIOR AID, FIELD

Duties: To run tape or levelling rod; to perform other miscellaneous subordinate duties in survey party in field or office, as directed.

Qualifications: Education equivalent to graduation from high school.

The completion of each full year of post-graduate work in the specific subject of study or investigation appropriate to a particular service or branch of service shall be considered the equivalent of one and one-half years of general experience, but such substitution shall not thus be made for more than four years of such experience or be considered as reducing the requirements in any grade of the number of years engaged in the conduct or direction of responsible work.

RESULTS OF INVESTIGATIONS

An analysis of the federal, state, and municipal returns from questionnaires received up to the date of the committee report, December 15, 1919, shows them to be much better than those obtained in the investigation made by the American Society of Civil Engineers in the years 1913-1917. This is due to better coöperation on the part of responsible department heads. The financial status of 10,089 men has now been revealed as compared with a total of 6378 men who replied to the previous inquiry. It also appears that the respondents in the case of the previous investigation were largely confined to the classes receiving a maximum compensation, whereas the present returns cover a much broader range of salary.

Returns from men in federal service representing 16 engineering bureaus in civil establishments and 4 engineering bureaus in the Navy Department, and holding positions of decreasing responsibilities from chief administrative officer having full charge of organization, including determination of policy, to subordinate duty not requiring any special education, training or originality, show a corresponding gradual decrease in average salaries from

approximately $6000 to $1000 in civil establishments and from $10,000 to $1400 in the Navy Department.

In state service 35 questionnaires from 27 states show a total of 1166 men in professional positions, ages ranging from 21 to 70. The average salary on July 1, 1919, was $2070 as compared with $1590 four years previous. This is an increase of 30 per cent, whereas a 72 per cent increase is recommended, making the average salary $2730. In sub-professional position there is represented 1056 men, ages 18 to 50. The average salary on July 1, 1919, was $1290 against $995 in 1915, an increase of 30 per cent. The engineers in charge advocate an average salary of $1470, a 48 per cent increase.

In municipal service, analysis of 66 questionnaires from 40 cities shows a total of 1478 men in professional positions, ages ranging from 25 to 70. The average salary on July 1, 1919 was $2370 as compared with $2230 in 1915, showing an increase of 6.5 per cent. The engineers in charge recommend an average salary of $3020, which is a 36 per cent increase. In sub-professional positions the returns show 1839 men, ages 17 to 65, average salary 1919, $1370 against $1160 in 1915, an increase of 18.5 per cent. The recommendation is for an average salary of $1700, a 47 per cent increase. It is thus disclosed that the average compensation for grades representing 68 per cent of the engineers in the federal service, other than the War Department, and 80 per cent of those in state and municipal service, is less than is required for the support of a family on a scale sufficient to provide for necessities (assumed at $2200 per annum), to say nothing of the expense of giving children anything like the education with which the bread-winner was equipped.

It would seem reasonable to assume that men in the "Junior Aid" grade have not reached an age which would require compensation sufficient to support a family, but that the salary limitation for men in higher grades should clearly be sufficient to meet this need. On this basis it is safe to state that with anything like suitable compensation, not more than about 25 per cent of the entire service, if properly organized, should receive less than $2200 per annum. The investigation made by the State and Municipal Section shows that the average age of the present incumbents of the lowest grades is actually about 27 years; if they are to be adequately provided for as permanent employees, the percentage of men to receive less than $2200 is clearly negligible.

A comparison with the pay of the industrial worker who serves under the engineer also bears testimony to the fact that, while admitted by none as to value, the actual compensation for brawn is to-day greater than for engineering brain. The need for setting up some scale of compensation for the engineer to correct this serious condition is, therefore, obvious, as is also that for the inquiry now being carried on by the Committee. Unless a radical improvement can be brought about, it seems evident that the profession cannot attract or retain men of the caliber required to command the respect in which it has heretofore been held by the public, and that so long as they are continuously struggling with the problem of making even a bare living, their efficiency will be minimized and their incentive to work with other than a purely selfish interest will be lacking.

That a serious condition of unrest exists in the municipal and state services is clearly evidenced by explicit statements in this respect in 44 per cent of the questionnaires returned, while in only 13 of these services were conditions as to morale reported to be satisfactory.

RECOMMENDATIONS

From the investigation made by each of the sections of the Committee, it appears that the heads of sixteen engineering bureaus in the Federal Government (excluding the Navy Department) have recommended an increase in present compensation averaging about 59 per cent, while similar increases in the State and Municipal Services, as recommended by the engineering heads, average 26 per cent.

As a result of the inquiry now in progress under the direction of the Congressional Joint Commission on Reclassification of Salaries, the attention of all members of the federal service has been drawn to this question in such a way as to make it one of close study and analysis, which condition doubtless accounts for the comparatively modest recommendation made by the representatives of the state and municipal services, whose reply to our inquiry has been individual and who have doubtless been confronted with the necessity of recognizing relationship to other workers in the same services in whose interests no concerted move of this character has been attempted.

The Committee is impressed with the method which has been followed by the Federal Section in setting up a standard of compensation based on a readjustment to the new conditions as to cost of living, this being dependent on an award made on October 24, 1918 by the Shipping Wage Adjustment Board, which was designed to provide uniform national wage scale for all shipbuilding workers, including a scale of compensation for draftsmen and copyists. It is also understood that this wage scale, which is generally known as the Macy Scale, has since been adapted with modifications to the needs of certain bureaus in the Navy Department. In the accompanying diagram there is illustrated a comparison of the compensation fixed under the Macy Scale with the maximum rates suggested by the Federal Section. A further comparison has also been made with scales proposed by other organizations, which seem to justify the schedule of salaries now suggested by the Committee for discussion, which is as follows:

Grade	Total Years Experience Required to Qualify		Salary Range	
	With Professional Degree	Without Professional Degree	Minimum	Maximum
8—Junior Aid	[illegible]	0	$1080	$1560
7—Aid	[illegible]	2	1680	2400
6—Senior Aid	[illegible]	5	2520	3240
5—Junior Assistant Engineer	0	4	1620	2580
4—Assistant Engineer	2	6	2700	4140
3—Senior Assistant Engineer	5	9	4320	5760
2—Engineer	8	12	5940	No limit
1—Chief Engineer	12	16	8100	No limit

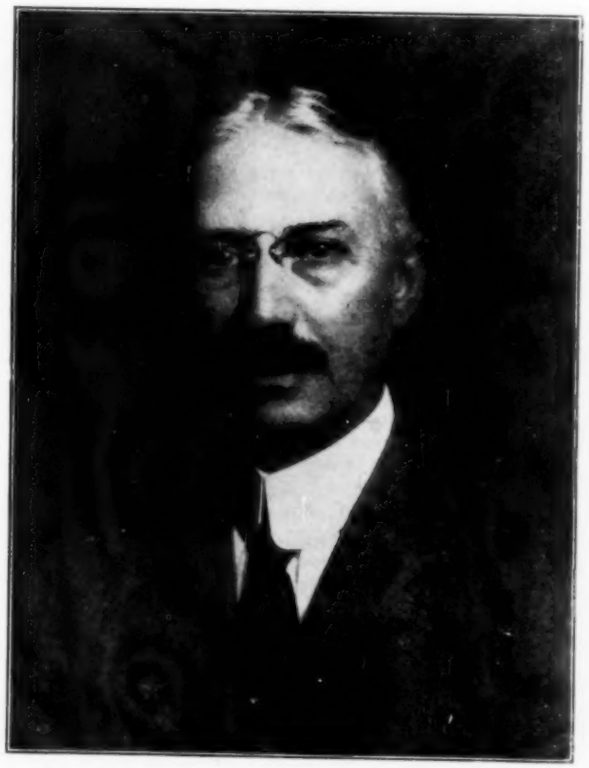
Applying the average proposed salary to the present incumbents of these positions as reported in the state and municipal services, it will be found that there would be a resulting increase in annual compensation totalling about $5,500,000 as compared with a total increase of $2,500,000 recommended by the service heads, against which, however, should be charged the economy growing out of the increased efficiency brought about by a restoration of morale.

The Committee is not prepared at this time to recommend the adoption of any definite schedule of compensation, and it is not at all clear as to the wisdom of fixing even a minimum limit on the highest grades of service or of keeping the maximum of one grade below the minimum of the grade above, all of which questions are now receiving its serious consideration, as is also the question concerning the provision to be made for advancing within the limits of a grade, for which a plan is suggested by the Federal Section. Under this plan it is proposed at yearly intervals, through ratings determined by a Personnel Board, to provide for awarding an increase in compensation to three-fourths of the men in a grade receiving less than the maximum compensation of the grade, who through fitness and industry have shown themselves to be of increased value to the service. Those in the highest third of this preferred list would each receive the maximum rate of increase, which under the proposed scale would be $480, while each of the next two-thirds would receive an increase of $240, the latter figure corresponding with what would then be the average increase for all of the men in the grade.

It is also the opinion of the Committee that, pending the completion of the investigation, the scale of compensation presented and the plan for promotion within a grade is adaptable to general use in all branches of engineering service. The Committee believes, however, that a general discussion of this question is desirable.

CHARLES FREDERIC RAND RETIRES AS PRESIDENT OF THE UNITED ENGINEERING SOCIETY

FOR six years Charles Frederic Rand has been a member of the Board of Trustees of United Engineering Society, the first two as representative of the American Institute of Mining Engineers, and the last four in the presidential chair, and under his able and earnest guidance much has been accomplished. His term of office as president has just expired and upon the occasion of his retirement the Council of The American Society of Mechanical Engineers recognized his services by presenting to him framed resolutions appreciative of his accomplishments. Mr.



CHARLES FREDERIC RAND

W. M. McFarland, Mem.Am.Soc.M.E., and one of its representatives on the Board of Trustees of the United Engineering Society, in presenting the resolutions said in part:

It is always a pleasure to find that the faithful and efficient performance of duty has been appreciated by those for whose benefit it has been done, and it is a still greater pleasure when this appreciation is accompanied by its definite expression at a time when it will be a satisfaction and a slight reward to the one whose actions are commended.

With the realization of the fact that with this meeting the service of our esteemed associate, Mr. Charles F. Rand, as President of the United Engineering Society comes to a close by the termination of his service as a member, the representatives of The American Society of Mechanical Engineers brought this fact to the attention of the Council of that Society and took occasion to praise the devotion to the interests of united engineering which had been shown by Mr. Rand, first as Chairman of the Finance Committee and later as President.

The Council thereupon passed a suitable resolution expressive of their appreciation of Mr. Rand's work and directed that it be suitably engrossed and presented to him.

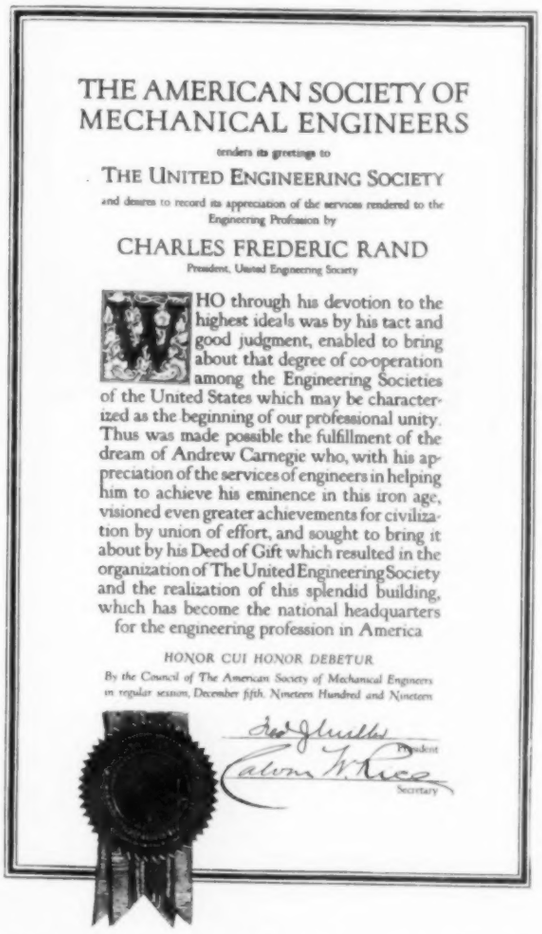
The pleasant duty of presenting these resolutions to Mr. Rand has been delegated to me, and it gives me very great pleasure to transmit to him this expression of the appreciation by one of the great American engineering societies for the splendid work which he has done in advancing the united interests of the engineers of America.

I feel that I am not only voicing my own sentiments but those of the entire Board when I express the deepest regret that the termination of his services will deprive us of the benefit officially of his ability, tact and wise judgment in the administration of the affairs of United Engineering Society, and of the great pleasure which it has always been to be associated wtih him personally. I feel very sure, however, that he will always be ready to respond to any call for help which he can give us unofficially.

Mr. Rand is widely known as a mining engineer. He has done considerable work both in this country and abroad, and in 1913 he was decorated by the King of Spain for his notable efforts and accomplishments in advancing the mining industry of that country. Mr. Rand occupies an active and honored position in the affairs of the American Institute of Mining and Metallurgical Engineers and during the year 1913 served as president. He is now one of the directors of the Institute.

During his term of office the activities of the United Engineering Society have greatly expanded. The size of the Engineering Societies Building has been increased by the addition of three stories, two of which are now occupied by the American Society of Civil Engineers. There has thus been brought under one roof the headquarters of the great national engineering societies and this has made for more coöperation along every line.

The Engineering Societies Library has also greatly increased both as to size and the scope of its work. There have likewise been inaugurated two movements of considerable importance to the engineering profession at large. These are the Engineering Foundation for the advancement of research, created by



THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

tenders its greetings to

THE UNITED ENGINEERING SOCIETY

and desires to record its appreciation of the services rendered to the Engineering Profession by

CHARLES FREDERIC RAND

President, United Engineering Society

WHO through his devotion to the highest ideals was by his tact and good judgment, enabled to bring about that degree of co-operation among the Engineering Societies of the United States which may be characterized as the beginning of our professional unity. Thus was made possible the fulfillment of the dream of Andrew Carnegie who, with his appreciation of the services of engineers in helping him to achieve his eminence in this iron age, visioned even greater achievements for civilization by union of effort, and sought to bring it about by his Deed of Gift which resulted in the organization of The United Engineering Society and the realization of this splendid building, which has become the national headquarters for the engineering profession in America

HONOR CUI HONOR DEBETUR

By the Council of The American Society of Mechanical Engineers in regular session, December fifth, Nineteen Hundred and Nineteen

President

Secretary

a gift of $200,000 from Mr. Ambrose Swasey, and Engineering Council, an organization devoted to a consideration of matters pertaining more particularly to the engineer's relation to public welfare. Both of these organizations have contributed largely toward the advancement of the engineering profession, and Mr. Rand's participation in their activities has always been helpful and sympathetic.

LIBRARY NOTES AND BOOK REVIEWS

United Engineering Societies Library Issues Annual Report

The Library Board of the United Engineering Societies Library, which collection embraces the libraries of the American Society of Civil Engineers, The American Society of Mechanical Engineers, the American Institute of Electrical Engineers and the American Institute of Mining Engineers, has just issued its annual report for 1919.

The officers of the Board for the year 1919 were E. Gybbon Spilsbury, Chairman, Samuel Sheldon, Vice-Chairman, and Harrison W. Craver, Secretary. The four societies were represented on the Board as follows:

AMERICAN SOCIETY OF CIVIL ENGINEERS
Alfred D. Flinn — Arthur P. Davis
John A. O'Connor — Willard Beahan
Charles Warren Hunt

AMERICAN SOCIETY OF MECHANICAL ENGINEERS
Jesse M. Smith[1] — William N. Best
Walter M. McFarland — L. P. Breckenridge[2]
Andrew M. Hunt — Calvin W. Rice

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS
E. Gybbon Spilsbury — Alex. C. Humphreys
George C. Stone — John H. Janeway
Bradley Stoughton

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
Samuel Sheldon — W. I. Slichter
Edward D. Adams — A. W. Kiddle
F. L. Hutchinson

The year has been marked by an increased use of the Library in every direction. The number of readers during 1919 was 22,042, an increase of 6979, or 46 per cent over 1918. The attendance after six in the evening was 15 per cent of this, or 3470. The average daily attendance was 72.

Over 2000 telephone inquiries were received during the year and approximately 1500 letters which did not require elaborate investigation were received and answered. In other words, over 3500 persons not represented in the attendance figures nor in the records of the Service Bureau have been helped by the Library.

As in previous years, the Service Bureau has cared for the work requiring extended research, the preparation of translations, and copies of articles and bibliographies. During the year 552 searches, chiefly bibliographic, were prepared in answer to specific inquiries. Of these, the classification of searches by branches of engineering shows the largest number to have been made in the field of mechanical engineering; mining and metallurgical engineering ranking second. Some of these bibliographies were of great extent, requiring the time of one or two people for weeks and even months; and the work done exceeded that in 1918 by an amount greater than the increase of 44 in the number of searches indicates. The number of translations made was 71, containing 227,300 words. In 1918 there were 78 translations, amounting to 258,080 words. The orders for photographic copies of articles amounted to 2319 and required 23,951 prints. In 1918 there were 1150 orders for 6306 prints. This increase of 101 per cent in orders shows the wide appreciation of this form of assistance, which appeals particularly to those far from libraries. Copies have been made for engineers in every continent.

The resources of the Library, on January 1, 1919, were:

	Volumes	Pamphlets	Total
Accessioned material	104,858	31,034	135,892
Unaccessioned material	13,962	7,941	21,903
Total	118,820	38,975	157,795

By December 31, 1919, all unaccessioned material had been examined and either accessioned or placed among duplicates. At that date the permanent collection contained a total of 152,091 volumes, pamphlets, maps and plans, and searches. There were also on hand 3958 duplicate volumes and 2076 duplicate pamphlets.

The receipts during the year were:

	Gift	Purchase	Total
Volumes	2,384	553	2,937
Pamphlets	3,205	232	3,437
Maps and plans	118	...	118
Searches	....	...	501
	5,707	785	6,993

As in former years, the Library has received considerable important material by gift. The majority of the technical publications of American publishers have been sent for review in the publications of the Founder Societies, and there have also been many valuable gifts from individuals.

The technical work of the Library during the past year consisted principally in recataloging. A complete report of this work has been prepared by Harrison W. Craver, Director of the Library, and was published in the September 1919 number of MECHANICAL ENGINEERING, page 782. Arrangements for the work were made in May, and Miss Margaret Mann, formerly Chief Cataloger of the Carnegie Library of Pittsburgh, was engaged as cataloger. The work was begun on July 1, since which time the cataloging of new accessions and the recataloging of old material have proceeded simultaneously.

At the end of the year all unaccessioned material had been examined and either cataloged, listed as duplicates or discarded as valueless. The number of volumes completely cataloged was 6671, while 2210 duplicates had been listed, 374 searches had been cataloged and 1612 volumes added to the records as additions to existing sets. An index to the new catalog, containing 2920 entries, had been compiled and 6899 cards had been added to the catalog. The speed of the department has increased at a rapid rate as preliminary points have been settled and methods of procedure determined. The total work of the catalog department during the year, including that prior to the reorganization of the department, was 3009 volumes, pamphlets, maps and plans, and searches cataloged, and 5984 recataloged, totaling 8993. These figures, while they express the net results, are by no means an accurate index of the amount of work done. Much time is spent in collecting sets from their various locations, in correcting inaccurate records and in collating sets of periodicals and Government publications.

Changes in the staff have been less frequent than in previous years, and the effect of experience has been favorably shown in more helpful service.

The new system of cataloging the Library substitutes for all the old catalogs an author catalog and a classed subject catalog, the latter to be accompanied by a very full index. A classed subject catalog enters a book in that place in the catalog where all similar entries on the subject are collected. The author catalog will enable the reader to find a book when the name of the author is known, to find what books by any author are in the library, and also the various editions available; translations as well as their originals will be shown. The subject catalog will enable the reader to find a book when the subject is known, and will exhibit the resources of the Library in orderly form on every chief and most subordinate topics within its chosen field. The alphabetical index will comprise the names of the subjects of knowledge upon which the Library possesses important books or pamphlets, and it will at once direct the user to that section of the subject catalog where these books are listed and to the department of the Library where these works are shelved. When these catalogs are completed the catalog equipment of the Engineering Societies Library will be as complete, detailed and satisfactory as it is possible to make it, as well as a true and helpful guide for all reasonable methods of approach by readers.

[1] Resigned May, 1919.
[2] Succeeded Jesse M. Smith

BOOK REVIEWS

L'ALUMINUM DANS L'INDUSTRIE. Métal pur Alliages D'Aluminium. By Jean Escard. H. Dunod et E. Pinat, Paris, 1918. Cloth, 6 x 10 in., 272 pp., illus., 18 francs.

The subjects discussed include the manufacture of aluminum, its physical and chemical properties, soldering, the influence of mechanical treatment on its properties, and its applications in metallurgy, electrical and mechanical industries, etc. The constitution, properties and uses of the various aluminum bronzes and alloys of aluminum with various metals, both common and rare, are described, and a final chapter treats of alloys with silicon, aluminum carbides and nitrides, and several alloys for special purposes. The volume gives a concise survey of present knowledge of aluminum.

APPLIED SCIENCE FOR METAL WORKERS. APPLIED SCIENCE FOR WOODWORKERS. By William H. Dooley. The Ronald Press Co., New York, 1919. $2 each.

These volumes present a course in the general principles of science, which gives particular attention to their applications in industry and is intended for use in vocational high schools, industrial schools, apprentice classes, etc. The general scientific matter in the two books is identical. Additional material relating specifically to the woodworking trades appears in one, while the other treats of metal-working in similar fashion.

BUILDING OF THE PACIFIC RAILWAY. The Construction-Story of America's First Iron Thoroughfare between the Missouri River and California, from the Inception of the Great Idea to the Day, May 10, 1869, when the Union Pacific and the Central Pacific joined tracks at Promontory Point, Utah, to form the Nation's Transcontinental. By Edwin L. Sabin. J. B. Lippincott Co., Philadelphia, 1919. Cloth, 5 x 8 in., 317 pp., 10 pl., 4 portraits, 1 map, $2.

Mr. Sabin's object has been to tell how the Pacific railway came into being; to describe the actual building operations by which the Union Pacific Railroad, from the Missouri River, and the Central Pacific Railroad, from the Sacramento River, were constructed in six years instead of the allotted fourteen. The book is a popular, readable account of the men who built the roads and of the methods used.

CLAY-PLANT CONSTRUCTION AND OPERATION. By A. F. Greaves-Walker. Brick and Clay Record, Chicago, 1919. Cloth, 6 x 9 in., 212 pp., 79 illus., $4.

In writing this work the author has attempted to explain in understandable English some of the problems of the manufacturer of structural clay products. Technical terms, formulæ, and theories have been avoided, and practical facts alone have been presented.

ELECTRICAL ENGINEERING PAPERS. By Benjamin G. Lamme. This volume contains a collection of the author's most important engineering papers presented before various technical societies and published in engineering journals and elsewhere from time to time. 1919. Published by Westinghouse Electric & Mfg. Co., Pittsburgh, Pa. Cloth, 6 x 9 in., 773 pp., illus., $2.50.

A collection of thirty-one papers and addresses which have appeared in various periodicals during the period from 1897 to 1918. These papers deal with problems of generator and motor design, the history of direct-current generators and of street-railway motors, and with technical training. The volume is published by the Westinghouse Electric and Manufacturing Company to commemorate Mr. Lamme's connection with it for thirty years.

ELEMENTARY PRINCIPLES OF AEROPLANE DESIGN AND CONSTRUCTION. A Textbook for Students, Draughtsmen, and Engineers. By Arthur W. Judge. James Selwyn and Co., Ltd., New York, 1919. Cloth, 6 x 9 in., 116 pp., 56 illus., 13 tables, $3.

Written to provide an inexpensive book, of an elementary nature, dealing with the fundamental principles of the design and, to a certain extent, the construction of airplanes. Follows the plan of the author's larger work, to which it may serve as an introduction.

FUNDAMENTALS OF CONTINUOUS CURRENTS OF ELECTRICITY. Book II of text-book series, School of Practical Electricity. By O. Werwath, assisted by Messrs. Vaughn, Hughes and Raeth. Electroforce Publishing Co., Milwaukee, Wis. 133 pp., illus., tables.

This book covers the fundamental principles of continuous current or direct electric current. It contains a nomenclature of electrical terms, discussion of Metric methods, basic electrical units, mechanical and electrical work and energy and detailed chapters on types of electrical circuits, electricity meters, resistance measurements, and electrical heating.

GUIDE TO THE STUDY OF THE IONIC VALVE. Showing its Development and Application to Wireless Telegraphy and Telephony. By William D. Owen. Sir Isaac Pitman and Sons, London. Cloth, 4 x 6 in., 59 pp., 12 illus., $1.

This little volume is intended to provide, for students of radiotelegraphy, an impartial, coherent record of the development of the ionic valve. References to the original sources of the information enable the reader to pursue his study of the subject.

INDUSTRIAL RECONSTRUCTION PROBLEMS. Complete Report of the Proceedings of the National Engineers, New York City, March 18-21, 1919. Paper, 6 x 9 in., 197 pp.

The papers presented at the conference dealt with a wide variety of problems connected with the reorganization of our industries on a peace basis. Consideration is given to questions of finance, commerce, production, labor, education, management, etc.

MACHINE TOOL OPERATION. Part I. The Lathe Bench Work and Work at the Forge. By Henry D. Burghardt. First edition. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 5 x 8 in., 326 pp., illus., tables, $2.

The author of this work has used his experience as a teacher of machine work in a technical high school to prepare a text-book for those who desire a knowledge of the principles and elementary operations of machine-shop work, suitable for use in technical and trade schools and in apprenticeship courses. While designed primarily for use in connection with lectures by an instructor, it is also useful for self instruction.

THE MANUFACTURE AND TESTING OF MILITARY EXPLOSIVES. By John Albert Marshall. First edition. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 6 x 8 in., 261 pp., $3.

This volume contains a concise account of the explosives used for military purposes, in which attention is directed to those points which have a direct bearing on their manufacture, testing and storage. An extensive bibliography is included.

METAL WORKER'S HANDY-BOOK OF RECEIPTS AND PROCESSES. Being a collection of chemical formulas and practical manipulations for the working of all the metals and alloys; including the decoration and beautifying of articles manufactured therefrom, as well as their preservation. Edited by William T. Brannt. New enlarged edition. Henry Carey Baird and Co., Inc., New York, 1919. Cloth, 5 x 8 in., 582 pp., illus., tables, $3.

Five new chapters have been added to the present edition of this work, describing methods for welding with the oxy-acetylene flame, thermit and electricity, for galvanizing and for die casting.

MILLIONS FROM WASTE. By Frederick A. Talbot. J. B. Lippincott Co., Philadelphia, 1920. Cloth, 6 x 9 in., 308 pp., $5.

This work is written to indicate certain of the most obvious channels through which wealth incalculable is being permitted to escape, as well to describe some of the highly ingenious efforts which are being made to prevent this wastage. While written essntially for the uninitiated, it will, the author hopes, prove of aid to those who are fully alive to the potential values of refuse. The volume is confined to those phases of the subject which are familiar to the average person.

MINERAL DEPOSITS. By Waldemar Lindgren. Second Edition. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 6 x 9 in., 957 pp., illus., tables, $5.

Mineral deposits are usually classified and described by the metals or substances which they contain; for instance, deposits of copper are described together, with little or no effort to separate them into genetic groups. This book is the outcome of a desire to place the knowledge of mineral deposits on the broader and more comprehensive basis of a consistent genetic classification and thus bring it into a more worthy position as an important branch of geology.

In this second edition, all of the chapters have been revised and several have been largely rewritten. A discussion of metallogenetic epochs has been added, as well as an index by elements. Some less essential descriptions have been excised in order that the book might not increase in bulk.

OIL ENGINES. Details and Operation. By Lacey H. Morrison. First edition. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 6 x 9 in., 472 pp., illus., tables, diagrams, $5.

This volume is intended for operators of oil engines. The details of construction of the more important oil engines manufactured in the United States are described and the proper methods of adjustment are explained at length.

THE PETROLEUM HANDBOOK. By Stephen O. Andros. The Shaw Publishing Co., Chicago, 1919. Flexible cloth, 4 x 7 in., 206 pp., illus., tables, $2.

In a book of pocket size, the author gives the fundamentals of each phase of the oil industry necessary to a clear understanding of the various operations entailed between the location of an oil well and the distribution of the refined products. The work is chiefly a compilation from the standard authorities, arranged for those who wish a brief, accurate account of the industry, devoid of unnecessary detail.

PRINCIPLES OF INDUSTRIAL ORGANIZATION. By Dexter S. Kimball. Second edition, revised and enlarged. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 6 x 9 in., 325 pp., 21 illus., 1 pl., 12 tables, $3.

This work, the first edition of which appeared in 1913, has been written to give young engineers a concise account of the salient facts regarding the most important economic and sociological problems with which they will be brought in contact, and to explain the origin and growth of the important features of industrial organization. The present edition has been revised, rearranged and enlarged.

PRINCIPLES OF REINFORCED CONCRETE CONSTRUCTION. By F. E. Turneaure and E. R. Maurer. Third edition, revised and enlarged. John Wiley and Sons, Inc., New York, 1919. Cloth, 6 x 9 in., 485 pp., illus., diag., pl., tables.

Like former editions, this work is intended "to present in a systematic manner those principles in mechanics underlying the design of reinforced concrete; to present the results of all available tests that will aid in establishing coefficients in working stresses; and to give such illustrative material from actual designs as will serve to make clear the principles involved." In the present edition the material has been considerably amplified and rearranged. Separate chapters have been devoted to the theory of flexure; bond and shear; and the design of beams. The experimental data have been reviewed. A new chapter on flat slabs has been added and the chapter on building construction extended.

RETAINING WALLS.—Based entirely on the Theory of Friction. By Pedro Dozal. Translated into English by R. T. Mulleady. First edition. M. A. Rosas, Buenos Aires, 1918. Cloth, 7 x 11 in., 161 pp., 62 illus.

The author presents a general theory in regard to the static pressures acting on a plane cutting an unbounded coherent, incoherent or liquid mass in equilibrium, and its application for the calculation of the pressures on retaining walls. The theory advanced differs from those presented by Rankine and other students of the subject and gives notably different results.

SCHOOL OF PRACTICAL ELECTRICITY. Book I of text-book series. By Oscar Werwath. Electroforce Publishing Co., Milwaukee, Wis., 1919. 60 pp., illus.

This practical text book, written by the president of the School of Engineering of Milwaukee in collaboration with several members of his faculty, sets forth the advanced methods of electrical instruction as taught at the School in a clear-cut, expository form, avoiding dry technicalities. It includes the history of electricity, detailed treatment of the telephone and telegraph systems, definitions of electrical terms, practical estimates and pointers regarding electrical workmanship and installations of all kinds, and experimental outlines for the electrical laboratory.

SELENIUM CELLS. The Construction, Care and Use of Selenium Cells with special reference to the Fritts Cell. By Thomas W. Benson. Spon and Chamberlain, New York, 1919. Cloth, 5 x 8 in., 63 pp., 18 illus., $1.50.

The lack of definite information on the construction of selenium cells has led the author to publish the results of some of his experiments. After a brief review of various types of cells, the book describes in detail the manufacture, maturing and testing of the Fritts cell, and concludes with an account of some applications and suggestions on the care of cells.

TIMBER. ITS STRENGTH, SEASONING AND GRADING. By Harold S. Betts. First edition. McGraw-Hill Book Co., Inc., New York, 1919. Cloth, 6 x 9 in., 234 pp., illus., maps, charts, tables, $3.

This volume, for engineers, manufacturers and users of lumber and wood material, is intended to meet the lack of a work on wood as a structural material, similar to existing handbooks on steel, concrete, etc. The methods of testing the strength of wood and wood products, such as telephone poles, packing boxes and vehicle parts, are described and the results of numerous tests by the Forest Service are tabulated. A table based on 130,000 tests, showing the average mechanical properties of 124 American woods, is given. Proper methods of seasoning wood are fully discussed. The grading rules of the different manufacturers' associations are given and the book closes with extensive statistics on the lumber produced and used in the United States.

MECHANICAL ENGINEERING LABORATORY, UNIVERSITY OF ILLINOIS

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supplying the laboratory or from the exhausts from the ammonia and brine pumps. A 24-in. by 12-ft. generator is installed for this purpose. A 16-in. by 19-ft. brine cooler is placed on the lower floor, and is arranged so that the brine may be circulated either through the reheater or the brine tank.

Both machines are completely equipped with thermometer wells and weighing tanks, and are especially arranged for accessibility.

INTERNAL-COMBUSTION ENGINES AND GAS PRODUCER

The section of the laboratory devoted to internal-combustion engines and the gas producer is located at the west end of the middle bay. At the extreme west of this bay is located a Smith gas producer rated at 75 hp. capacity. The producer (34) is complete with a gas-cleaning plant and is designed to operate continuously on bituminous coals.

In the opposite corner of the same bay with the gas producer there is to be installed an automobile-testing plant. This plant will be designed so as to be suitable for the testing of all sizes of pleasure cars and trucks up to five tons capacity. It is intended to measure the drawbar pull directly, and it will be possible to make various kinds of comparative tests on motor vehicle parts with this outfit.

While the automobile-testing plant is not yet installed, the laboratory has facilities to carry on tests of automobile, truck, tractor and even airplane motors. The principal unit of this equipment is a complete Sprague electric dynamometer (32a) of 150 hp. capacity. This outfit can be used either as an absorption or as a transmission dynamometer. At present a 4-cylinder Willys-Knight motor, a 4-cylinder Ford and a Peerless 6-cylinder motor (31) comprise the engine equipment for running tests with the dynamometer. A water brake designed by Dean C. R. Richards and built in the Mechanical Engineering Shops of the University of Illinois is shown in the plan view connected to the 6-cylinder 70-hp. Peerless motor (31).

The first large unit in the stationary gas-engine equipment is a single-acting, four-cycle horizontal 10-in. by 19-in. Otto engine rated at 25 hp. at 220 r.p.m., piped to the gas producer and supplied with the gas from the producer when desired.

There is also installed a smaller Otto single-acting, four-cycle 5¾-in. by 12½-in. gas or gasoline engine (29) rated at 10 hp. at 300 r.p.m.; a 9-in. by 9-in. single-acting four-cycle Bogart engine (28), which is rated at 10 hp. when running at 315 r.p.m., and may be operated on either illuminating gas or gasoline; a Mietz and Weiss single-acting 9-in. by 10-in. engine (27), rated at 12 hp. at 340 r.p.m., and using kerosene as fuel with a hot-bulb type of ignition; and a Sargent 10-in. by 20-in. tandem double-acting four-cycle "complete expansion" engine (26), rated at 50 hp. at 250 r.p.m. and using illuminating gas for fuel. Mr. Sargent, the designer and inventor of this engine, is an alumnus of the College of Engineering, University of Illinois.